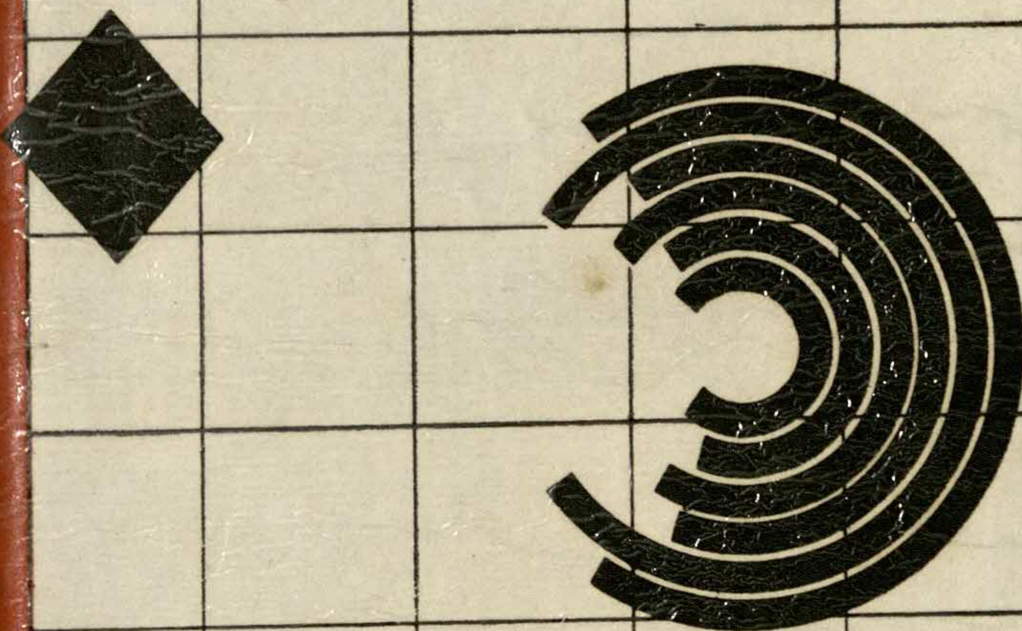
PERSPECTIVE IN PHYSICS EDUCATION:

A PIAGETIAN APPROACH



N.N. PANDEY

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Nagendra Nath Pandey

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Introduction

The development in science and technology has influenced every aspect of human life. It has thrown new challenges before life. The development of science has, however, not merely proved a boon for man. It is used simultaneously for the good of mankind and fulfilment of evil designs. Actually, science is neutral. It depends how it is used. Atoms can be used for peace and war both. The second world war appears to be a turning point in the history of science. The scientific development in the post war period is unprecedental in its speed and rapidity. The scientific knowledge has multiplied.

The demand of time necessitates that all citizens in schools or in community must have some understanding of science and technology along with its up-to-date role in society. There is a real problem of the organization of science curricula in this changed situation. Teaching of science and scientific concepts has become a difficult task. The teacher has also to decide about the quantum of knowledge to be imparted to students. Science is important for man but a decision regarding as to what is to be taught to students at a particular level will have to be taken. Things may be important but every thing cannot be taught at a particular level.

Another problem is how to impart instructions in science. The practice of teachers imparting lessons to students leads to verbalism and passivity. It is, therefore, unscientific. A knowledge received by this method remains superficial and

does not improve the quality of mind. It may make a person well informed but does not teach how to utilize scientific knowledge. According to Whitehead (1951), such an education is dangerous. The teaching of science must inculcate scientific temperament. It must also develop the capacity to utilize scientific knowledge for the solution of man's problem. The teaching of science must aim at establishing proper relationship between science and society.

But this is a difficult task. It cannot be achieved unless science becomes a part of our mental texture. Merely giving of information does not necessarily lead to the formation of concepts. But formation of concepts is necessary for the development of mind and scientific knowledge. The concept formation in general and concept attainment in particular, therefore, become an important process in the teaching of science because it ensures cognitive development. Thus, while teaching science, a teacher has to pay attention to this particular fact.

The study of cognitive process has now become an important area of psychological and educational investigations. Though the term cognitive development is of recent origin, not much unanimity has been achieved among psychologists on this issue. In spite of many divergent views, in the opinion of Murray (1985), there is a consensus among psychologists that changes introduced by the cognitive process are relatively stable and continue for a longer period.

According to mechanistic theories of cognitive development, this process involves certain ingredients which result from conditioning, association formation, imitative process, and modelling and mediational mechanisms. The believers in organismic theory postulate the existence of a system-activity. This system-activity has mechanisms of preserving or conserving the system, a mechanism which promote modification and flexibility in the system along with a regulatory principle by which the system is made more coherent, consistent and

general Murray (1985) finds that these theories provide sufficient explanation for linguistic and logical thought development.

Jean Piaget and his colleagues at Geneva worked out a theory of cognitive development which is thought to be the most satisfactory of the organismic theories of cognitive development. It is the most mature theory both from the perspective of specificity and completeness of the theoretical mechanisms and from the richness of the empirical findings the theory has generated (Boyle, 1969; Pulaski, 1971; Marek, 1981; Murray, 1985; Siegler, 1986). Peter Bryant (1982) also expresses similar view when he says,

> "Child psychology would have been a meagre thing without piaget. During the long period, his work was largely ignored by most psychologists, the subject tended to treat children as members of various remote and incomprehensible tribes or as slightly superior rats . . . It was descriptive and parasitic subject. Piaget rescued us from that . . . One was to develop a theory which was original and comprehensive. It is complicated, immensely complicated and few people are bold enough to claim that they understand it entirely. Yet many of the most important ideas in it are simple and flexible and it is these ideas which give the theory its power . . . The second main reason for Piaget's extraordinary influence on child psychology is his skill and ingenuity as an experimenter."

Piaget was the man to carry out the first systematic experiment on babies and gave a detailed description of their cognitive and social development. His conclusion was that child and adult thinking was qualitatively different. He was not interested in individual differences but in constancy of modes of conceptualization for all children irrespective of caste, creed or race. All children, he maintained, must go through certain stages of intellectual development in the same order.

1.1 Stages of Cognitive Development

According to Piaget, the process of cognitive development is not a process of continuous and quantitative improvement which remains qualitatively unchanged throughout the life of an individual. The cognitive development during childhood and adolescence differs. In his opinion this development is an evolutionary process having distinct developmental phases and subphases.

The period of cognitive development can be divided into four stages—each stage denoting different organizational pattern. These stages occur as per definite sequence and satisfy certain set of criteria: (a) qualitative change in cognitive contents, (b) a culturally universal sequence in the overall progression of stages, (c) inclusion of the cognitive structures of each preceding stage in each subsequent stage, and (d) an overall integration of the structures of each stage (Brainerd, 1978). The four stages which Piaget (1953) propounds are as follows :

I Sensory—motor stage (birth to 2 years)

II Pre-operational stage (2 years to 7 years)

III Concrete-operational stage (7 years to 11 years)

IV Formal-operational stage (11 years to 15 years)

Each stage suggests the potential capacity and probable behavioural pattern of children. The ages at which children reach a stage may vary from child to child and from culture to culture, but the sequence of the stages remains the same (Piaget, 1972).

Sensory-motor stage : The sensory-motor stage starts with reflexes and ends when language is acquired at the initial stage. During this period internalized thinking is absent. It is manifested by overt behaviour. Flavell (1963, p. 86) has described the child during this period as,

> "... (moving) from a neonotal, reflex level of complete self-world differentiation to a relatively coherent organization of sensory-motor actions vis-a-vis his immediate environment. The organization is an entirely 'practical' one, however, in the sense that it involves simple perceptual and motor adjustment to things rather than symbolic manipulations of them".

There are six substages which mark the infant's progress during this period. The first substage is from birth to one month in which the child shows little besides the reflexes with which he is provided at the birth. At the second substage, which is from one to four months, modification and intercoordination of reflexes and experiences take place. At the third substage (4 to 8 months) actions oriented towards external objects and events outside and beyond his own body start. During the fourth substage (8 to 12 months) intentional means—ends coordination begins. The child attempts to find out new means and to pursue some novel practice for his own sake at the fifth substage which lasts from 12 to 18 months. At the sixth substage, which lasts from 18 to 24 months, the child begins to make internal and symbolic representation to sensory-motor problems and invents solutions by implicit rather than explicit trial and error behaviour.

Pre-operational stage : This stage lasts approximately from 2 to 7 years of age. During this period children acquire the internalization of thought process which they lacked as infants. But the internalization of actions does not take place at this stage in which the child can make use of a system of operations. The development during this period can be conceived of as preparing the way for the achievement of operations through increasing coordination of assimilation and accomodation in the child's symbolic activities. The child's thinking is mostly dominated by his perceptions which is the limitation of pre-operational thought. The child at this stage fails at conserving (understanding that quantitative relationships between two objects remain invariant in the face of irrelevent perceptual deformations of one of the objects) number, length,

weight, area, volume, and related tasks. He feels difficulties in understanding the effect of different points of view on the same event and in the integration of information. According to Piaget (Ripple and Rockcastle, 1964; p. 9),

> "In a second stage, we have pre-operational representation—the beginning of language, thought, or a representation. But at the level of representational thought, there must now be reconstruction of all that was developed on the sensory-motor level. That is, the sensory-motor actions are not immediately translated into operations. Infact, during all this second period of pre-operational representations, there are as yet no operations. . . Specifically, there is as yet no conservation which is the psychological criterion of the presence of reversible operations".

The pre-operational period is divided into two. The first ranges from two to four years. This period is marked by egocentric speech and primary dependence on perception. The child carries on egocentric speech to associate with what he does without intending to use the same as a vehicle for communicating others. Children's heavy dependence on perception is evident in problem-solving when they draw conclusions from what can be directly seen or heard rather than what they might recall about the permanent characteristics of objects and events. The second period is between five to seven years. During this period intuitive thought develops. It is a transitional phase between child's sole dependence on perception and use of logical thought in problem-solving. While during the earlier years children's thinking suffers from centering (focussing exclusively on one dimension of a situation), but during this period they begin to recognize that more than one factor at a time influences an event in a coordinated manner.

Concrete operational stage : This stage ranges from seven to eleven years of age. At this stage children's thought process loses their intuitive character. It becomes more logical. Piaget and Inhelder (1969) maintain that entry into this stage

is the turning point in the entire course of cognitive development. At this stage, children bear marked resemblance to adults than the children of the first two stages. However, the mental operation is limited to concrete and tangible information. This does not mean that the child should see or touch the actual object when he works on a problem. The problem itself involves identifiable objects that are either directly perceived or imagined. Certain logico-mathematical structures make very good models of the actual organisation and of the process of cognition during concrete-operational period. If Piaget says that the classificatory behaviour at the age of eight indicates the child's grouping of logical class addition, he means that thought organization in the classificatory area has the properties of 'Group', i.e., reversibility, identity, associativity, composition, which define this logico-algebraic structure. Piaget (Ripple and Rock-castle, 1964; p. 9) asserted that,

> "In the third stage the first operations appear but I call these concrete operations because they operate on objects, and not yet on verbally expressed hypotheses. For example, there are the operations of classification, ordering, the construction of the idea of number, spatial and temporal operations, and all the fundamental operations of elementary logic of classes and relations, elementary geometry and even of elementary physics".

Thus, Piaget holds that mental operations at this stage can be grouped into two broad categories : (a) logico-arithmetic operations and (b) spatial operations. The logico-arithmetic operations involve discontinuous information and spatial operations involve continuous information. The thought process at the concrete-operational stage has certain limitations.

Flavell (1963, pp. 203-4) has enumerated limitations of concrete operations as follows :

"1. Concrete operations are concrete relatively speaking; their structuring and organizing activity is oriented

towards concrete things and events in the immediate present.

2. The effect that the concrete-operational child is still (relatively) bound to the phenomenal here and now results in a second limitation : he has to vanquish the various physical properties of objects and events (mass, weight, length, area, time, etc.) one by one because his cognitive instruments are insufficiently 'formal', insufficiently detached and dissociated from the subject matter they bear upon, to permit a content-free, one-for-all structuring.

3. The various concrete-operational systems (e.g., the logical groupings) exist as more or less separate islets of organization during the 7-11 year period; they do not interlock to form a simple, integrated system, a system by which the child can readily pass from one substructure to another in the course of a single problem".

Inhelder and Piaget (1958, p. 250) have generalized the following in reference to concrete operations :

> "In sum, concrete thought remains essentially attached to the empirical reality. The system of concrete operations . . . can handle only a limited set of potential transformations. Therefore, it attains no more than a concept of 'what is possible' which is a simple (and not very great) extension of the empirical situation".

Formal-operational Stage : This stage develops approximately from 11 to 16 years. According to psychologists, this is the period of emotional instability which may cause adjustment difficulties. Erikson (1963, 1968) also supports this view. But for Piaget, it is the most exhilarating and productive period during which the adolescent demonstrates commendable thinking and reasoning potentialities (Brainerd, 1978).

The adolescent at this stage develops the capacity to engage in propositional logic. He is neither restricted by what he directly sees or hears, nor is restricted to the problem he immediately encounters. The adolescent may now imagine the dimensions of a problem—past, present or future—and devise hypotheses about what logically might occur under different combinations of factors. It is the highest level in the development of mental structure. Formal-operational thinkers are capable of reasoning verbally even in the absence of concrete object (Piaget, 1973). It may even surpass every day experience as it is not tied up with perception and memory. The adolescent begins to imagine the situation under certain hypothetical sets. He can set up a hypothesis in a given situation, deduce what would happen if it was true, check and verify if the facts in front of him are consistent with his deductions from the hypothesis. If they are not, then another hypothesis is formulated. Thus hypothetico-deductive thought has been achieved, for he was able to reverse the direction between possibility and reality (UNESCO-UNICEF Report, 1974). The child is able to manipulate symbols and deal with ideas verbally without the necessity for an intervening arrangement of physical objects; he is now capable of thinking systematically and at purely abstract level.

With the formal-operational thought the child can understand in an analytic rather than in an intuitive sense. In every event he finds greater interest in looking for reasons. He can see the point in making hypothesis, and can deduce the relationship if the situation is simplified to one variable at a time. He finds some causative necessity behind a relation established associatively. He can perceive the type of proportionality in a concrete situation. During the later stages of formal thought the adolescent knows that in a system with several variables he must 'hold other things equal' while investigating one variable at a time. Direct and inverse proportionality is readily available for perceiving and formulating relationships. One who has entered the stage of formal thought, " . . . is an individual who thinks beyond the present and forms theories about everything, delighting

especially in considerations of that which is not" (Piaget, 1966; p. 148).

Thus, the thought process of formal-operational stage has four distinct features (Sheehan, 1970). The first is that one would not accept reality or empirical results from concrete phenomena unless and until it is verified throgh all possible consequences. According to Inhelder and Piaget (1958, p. 251),

> " . . . it is reality that is now secondary to possibility. Henceforth, they conceive of the given facts as that sector of a set of possible transformations that has actually come about; for they are neither explained nor even regarded as facts until the subject undertakes varifying procedures that pertain to the entire set of possible hypotheses compatible with a given situation".

They further stated that, " . . . the most fundamental property of formal thught is this reversal of direction between reality and possibility" (Inhelder and Piaget, 1958; p. 255).

The second feature of this thought process is that one would attempt to verify reality by creating possible solutions in hypothetico-deductive statements. He would consequently be able to move in the direction of reality from the realm of possible. Inhelder and Piaget (1958, p. 251) stated that,

> " . . . formal thinking is essentially hypothetico-deductive. By this we mean that the deduction no longer refers directly to the perceived realities but to hypothetical statements—i.e., it refers to propositions which are formulations of hypotheses or which postulates facts or events independently of whether or not they actually occur".

The third feature is that one at the formal-operational stage would formulate statements about possible solutions in

the form of propositions. He would be capable of generating second-degree operations or propositions that were interpropositional. (Flavell, 1963; p. 205) interprets Piaget by stating that,

> " . . . formal thinking is above all propositional thinking. The important entities which the adolescent manipulates in his reasoning are no longer the raw reality data themselves, but assertations of statements—propositions—which 'contain' these data".

The fourth feature is that a student at the formal-operational level would arrange all variables in a situation according to all possible combination of these variables. Inhelder and Piaget (1958, p. 254) stated that,

> " . . . the most general property in terms of which we can characterize formal thought is that it constitutes a combinatorial system, in the strict sense of the term".

Piaget consistently maintained that congnitive development is tied to the whole process of embryogenesis, especially as it concerns the development of the nervous system and mental functions (Piaget, 1964). Recent research by Epstein (1974, 1978) has provided valuable insights into the maturation process, particularly the brain growth and supplies as one possible source of neurobiological support for the Piagetian model of cognitive development. Epstein's research indicates that the growth of human brain occurs in spurts rather than in simple linear increments across time.

Epstein's findings regarding the chronology of brain growth spurt periods are congruent with Piaget's timing of the onset of each of the cognitive developmental stages. Epstein identified a fifth stage of brain growth, however, for which there was no counterpart in the original Piagetian model. Piaget (1972) pointed out the possbility of the existence of such a stage. Arlin (1975) and Riegel (1973) also proposed such a stage within the Piagetian and dialectical frameworks.

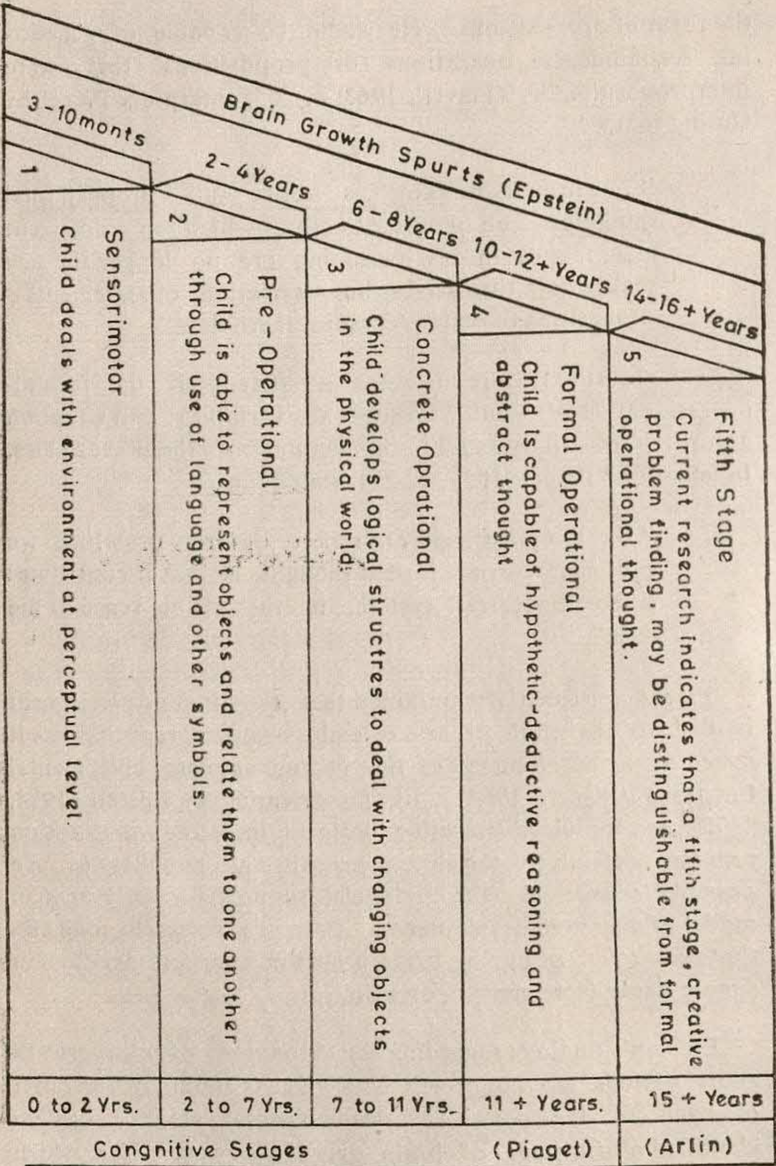

Fig. 1.1 : Parallel between Epstein's brain growth spurts and Piaget's stages of cognitive development (Brooks et al., 1983, p. 5).

Figure 1.1 illustrates the parallel between Epstein's brain growth periods and the Piagetian stages in the development of logical thinking, including the fifth stage.

Piaget's theory, strictly speaking, is not a psychological or educational theory. It is not concerned primarily with the explanation and prediction of psychological or educational phenomena, although it illuminates these phenomena. However, Piagetian theory is receiving wide attention in various countries as a source of insight into questions such as : How do children acquire knowledge ? How do children's thinking abilities and learning processes help children ?

1.2 Development of Knowledge

Piaget was much more a developmental psychologist than a learning theorist. For him, the term genetic is synonymous with developmental, and epistemology is a theory of knowledge acquisition. Thus, his genetic epistemology is devoted to a study of the developmental stages of children as they relate to their acquisition of knowledge. The goal of epistemology is to provide a theory of knowledge in whatever form it occurs. Piaget defines genetic epistemology as "the study of the mechanism of the growth of knowledge" (Piaget, 1957; p. 14). His studies are biologically oriented. Hence, he gives psychobiological factors preeminence and cultural learning factors a secondary place in the explanation of human behaviour.

Piaget's concept of knowledge differs from most of other theorists. In Piaget's opinion knowledge is a process, a repertoire of actions that a person performs whereas for others it is a store of information and belief. In Piaget's opinion, to know something means to act on that thing physically or mentally. The purpose of all behaviour or all thought, according to Piaget, is to adapt the organism to the evironment in more satisfactory ways. Adaptation is the essence of intellectual functioning. Adaptation is not merely survival (in the Drawinian sense of "survival of the fittest"); but

modification of the environment. Such functioning is a characteristic of living organisms at all levels; it is an ingredient of our biological inheritance.

Adaptation consists of two processes, assimilation and accommodation, which go on continuously in all living organisms. Accommodation and assimilation are called "functional invariants" because they are characteristic of all biological systems, regardless of the varying contents of these systems. Assimilation occurs whenever an organism utilizes 'input' from its environment and incorporates it. While assimilating, the individual simply attempts to "make some sense of" or derives some meaning from information received. The sophistication and accuracy of the interpretation, as derived by the individual, depends on his level of mental sophistication.

Assimilation is continuously balanced by accommodation, the process of adjusting to new and changing conditions in the environment, so that pre-existing patterns of behaviour are modified to cope with new information or situation. While assimilation involves the interpretation of acquired information, accommodation involves changing the structures used to assimilate information. For example, a baby learning to set his solid food with the help of a spoon must first learn to assimilate solid food by licking and chewing rather than by previous method of sucking. At the same time he must open his mouth and accommodate it to the size and position of the spoon, rather than the nipple he was using. In this way he adapts a new experience. These two processes—assimilation and accommodation functioning simultaneously, at all biological and intellectual levels, make possible both physical and cognitive development.

The cognitive development is essentially synonymous with change in cognitive structure—the form, shape or pattern of cognition during each of Piaget's stages of mental growth (Brainerd, 1978). Cognitive structure is the underlying

variable that controls intelligence at any given level of development. It is abstract to be only indirectly inferred. To some extent it is like the grammatical structure underlying language (Brainerd, 1978). For example; "A baby looks at a toy and picks it up". The structure of this event includes the means (looking, reaching, grasping) and end (stimulation from the object in hand). Each is related to the other, and it is this relatedness that Piaget calls structure (Phillips, Jr. 1969).

While adaptation is responsible for change of cognitive structure, the organization, another functional invariant, is responsible for the continuity of the cognitive structure across time and development. Organization is a basic inherited tendency of the organism to systematize and integrate actions, either motoric or cognitive, into coherent structure of a higher order. Hence, two experiences that may originate separately (e.g., looking at an object and grasping an object) may be eventually integrated into a higher level of action looking and grasping. This higher level of action does not wipe out the original action which may be used if occasion arises. Organization also accounts for the increasingly higher levels of complexity of the cognitive structure, that is, the patterns of action and thought associated with the major periods of development. While functioning adaptively, the baby is also developing intellectually. He is organizing his new experiences in various ways—differentiating, integrating categorizing. In Piaget's developmental psychology the baby is never a passive, helpless infant as some psychologists picture him, reacting only to loud noise and loss of support (Pulaski, 1971). He is an active and curious organism, reaching out, experimenting, seeking always to maintain a stable balance between assimilation and accommodation, between his inner reality and that of the world around him. The discrepancy between existing cognitive structure and a cognitive referent in the environment results in a disequilibrium which produces a reconstruction that brings the system back to equilibrium just as the body seeks to find a physiological state of equilibrium between exercise and rest.

Piaget called the process of achieving mental equilibrium as "equilibration". The concept of equilibrium is characterized by stability, compensation, and activity. The underlying assumption of equilibration is that the individual has encountered a situation producing disequilibrium. The degree of disequilibrium can be thought of as the difference between the existing cognitive structure and a cognitive referent in the environment. Equilibration represents the process of reconstructing the intellectual structure in order to incorporate the cognitive referents into the individual's organization of knowledge. Equilibration, consequently, is the factor which leads an individual from one level of cognive development to the next. Picget (Ripple and Rockcastle, 1964; p. 14) has stated that,

> "There is a sequence of levels. It is not possible to reach the second level unless equilibrium has been reached at the first level, and the equilibrium of the third level only becomes possible when the equilibrium of the second level has been reached, and so forth. That is, each level is determined as the most problem given that the preceding level has been reached. It is not the most probable at the beginning, but it is the most probable once the preceding level has been reached".

Steps involved in cognitive development are shown in Figure 1.2.

Some vital questions arise here. Once the organism is in equilibrium—what upsets equilibrium ?, what stimulates the child to achieve higher stages of cognitive development ?, why and how does he learn ? In answering these questions, Piaget recognizes the factors of maturation, experience and social transmission.

He stresses the importance of maturation in mental as well as in physical develpment. As cognitive structure develops, the child begins to use it just as he uses his muscles (Pulaski, 1971). A child cannot think like an adult because he simply

Step 1

Cognitive structures at an initial level of equilibrium

⇓

Step 2

Encounter requiring intelligent behaviour beyond present level of cognitive structures

⇓

Step 3

Disequilibrium of cognitive structures

⇓

Step 4

Adaptation of cognitive structures through assimilation and accommodation

⇓

Step 5

Cognitive structure organized at a new, higher level of equilibrium

Fig. 1.2 : Steps in the process of Adaptation (Sund, 1982; p. 37)

does not have the logical structures, the organization of thought, and the methods of reasoning which would enable him to deal with adult problems. But as he grows and matures, his mind becomes increasingly alert and active. He

explores and experiments until he finds a satisfactory answer and achieves equilibrium, at least for that stage of his development.

The second factor that explains intellectual development is experience, physical and empirical, that a child encounters while flying kites, playing with toys, counting objects, etc. Piaget insists that children must be allowed to have their own learning. Thought arises out of motor actions and sensory experiences which are internalized. The child who has had physical experience with concrete object, can then form a mental image of that object and act upon it in thougt which he had in actual experience in the past.

The third factor causing disequilibrium is social transmission. This consists of verbal instructions transmitted by teachers, parents and others in the process of education. When a child hears con tradictory or challenging statements, whether at home or school, his equilibrium is upset. He then tries to search an answer which enables him to achieve a new and higher equilibrium.

Inhelder and Piaget (1958, p. 243) state that the development of structures is dependent upon "... maturation of the nervous system, experience acquired in interaction with the physical environment and the influence of social milieu". These factors are necessary but not sufficient to explain congnitive development (Piaget, 1964). Equilibration seems to Piaget to be the "... fundmental and even the principal factor" (Ripple and Rockcastle, 1964 ; p. 10). It is fundamental in the sense that it mediates the influence of other three factors.

For Piaget, perception alone is not a reliable guide to knowledge. It is the previously elaborated understanding that enables one to make sense of what he has perceived. For example, when a liquid jar is poured into a relatively narrower jar, the child can "see" that nothing has been added or taken away. But he can not see it in a way which leads to the conclusion that

matter has been conserved until he can carry out a certain group of mental actions on the events before him. This is not through direct observations, but through the 'actions' one carried out upon one's own perceptions, not so much the actions of the body but those of mind, and thereby comes to know the world.

As stated earlier, to know something means to act on that thing physically or mentally or in both ways. With age, children gain more experience with direct physical knowing, while their nervous system also matures. As a result, they are freed from carrying out direct physical behaviour in order to know something. They come to produce mental images and symbols that represent objects and their relationship. Hence, older children "think about" things by carrying out interiorized actions on symbolic obects. When actions upon objects become interiorized and follow certain reversibility rules, Piaget names such actions as operations. The process of knowing takes place when information is processed by the use of logical operations. The mental structure for a particular concept is continuously enriched and developed as operations continually act upon it (Raven, 1972).

1.3 Concept of Operation

The cognitive differences between the pre-school and school child in Piagetian sense are that the school child seems to have at his command a coherent and intergrated system with which he organizes and manipulates the world around him while the pre-school child does not have at his command such a system. Cognition at all genetic level is best characterized as the appliation of real action by the child, either in relation to something in the milieu or in relation to other children's actions. Flavell (1963) notes that as the child progresses, his cognitive actions become more and more internalized, schematic and mobile, having more and more departure from concrete and substantial qualities. These new internal, now representational, cognitive actions gradually cohere to form increasingly complex and tightly integrated system of actions. These

systems are equilibrated, organized affairs, in the sense that one action may annual or otherwise compensate for another previously performed, and two actions can combine to produce a third, and so on. When cognitive actions are organized into close-knit totalities with definite, strong structure, Piaget (1966) calls them cognitive operations.

According to Piaget the idea of operation (activities of mind as opposed to the bodily activities at the sensory-motor stage) is contral to the entire understanding of the development of knowledge. All the changes that occur during the sensory-motor and pre-operational stages, serve to prepare the child for the advent of operations. Acquisition of operation is the single most important event which occurs during post-infancy cognitive development (Brainerd, 1978). In Piaget's opinion, the mental operation denotes the direction of cognitive development. Brainerd (1978) states that Piaget's stipulation that an operation must originate in action, excludes three important mental phenomena from the definition of operation namely, perception, memory and imagery. Perception is defined as veridical representation of facts evident to sensation ; memory as a process of making, storing, and retrieving mental memoranda about past events ; imagery as a process whereby static sensations, usually visual or auditory, are stored mentally. In each of these processes, there is an emphasis on passively recording events without intervening interpretation. By comparison, the emphasis in Piagetian operations is on actively transforming and interpreting reality.

Another characteristic of operations is that they are organized. To describe the mental organization of operations, Piaget has proposed abstract mathematical system. According to him, they are not just tightly integrated, but obey certain abstract rules. Of these rules, the two most important ones are Piaget's cognitive reversibility rules—inversion or negation and reciprocity reversibility or compensation (Brainerd, 1978). A direct inversion or negation of the process is possible (e.g., +5 is reversed by —5). A compensation or reciprocal change is also possible (e.g., 4×5 is a compensation for $20 \div 4$ or $20 \div 5$).

Operations assemble themselves into organized and integrated systems which Piaget calls *structures d' ensemble*. According to him mental operations never occur in isolation from each other. They are always assembled into system called structure of the whole. Within these systems, there is a large class of potential operations associated with actual operations. The distinction between operations that actually occur at a given time and those that might occur, is fundamental to the structure of the whole. The structure of the whole principle says that the operations that characterize any given stage of development, are not merely "associated" or "correlated" with each other, instead they are "originally" interrelated. For example, mouth, stomach and intestine are originally connected to form the digestive system.

Piaget (1966) has put forward the definition of an operation as "an action that can return to its starting point, and that can be integrated with other actions also possessing this feature of reversibility". Brainerd (1978) has defined operation as "a mentally represented action that obeys certain rules of organization and combines with other operations to form tightly integrated systems called structure of whole".

1.4 Need and Importance of the Study

Physics, as a discipline, demands keen observation of phenomena, correct measurements, extensive interactions with apparatus, wide experimentation and appropriate prediction. At the same time it is considered to be a difficult subject for students, and in some cases, incomprehensible (Cantu and Herron, 1978; Clement, 1982) because many of the concepts taught in schools can be assimilated by mature and disciplined mind of students who are conversant with the content area. Many of these concepts cannot be comprehended readily by secondary and higher secondary students because of the complexity of the logical organization of the concepts included in courses.

Results of studies indicate that many secondary school and college students have serious difficulties in fundamental concepts and principles in physics (Arons, 1979, 1980; Karplus, 1981; McDermott, 1982). Apparently, many students pass their physics papers without acquiring a proper understanding of some of the most important concepts that courses intended to teach. Students' interpretation of observed phenomena and laboratory experiences are frequently found to be scientifically different from the ideas which teachers wanted to convey. This is in the case of subject areas such as Mechanics (Viennot, 1979; Green et al., 1980; Trowbridge and McDermott, 1980; 1981; Clement, 1982; Minstrell, 1982), Heat and Temperature (Rosenquest et al., 1982), Gravity (Gunstone and White, 1981) and Electricity (Fredette and Clement, 1981; Fredette and Lockhead, 1980; Idar and Ganiel, 1982; Cohed et al., 1983).

Difficulties, which students experience while learning physics, are many, such as, abstractness of the concepts, required mathematical skill, reasoning requirement, etc. According to Cantu and Herron (1978) there is reason to believe that part of this learning difficulty is associated with the students' level of intellectual development as described by Piaget and Inhelder (1969). Piaget believes that all societies have certain unique characteristics and all individual in their cognitive development have certain universal characteristics (Evans, 1973). The research of Inhelder and Piaget has shown that there is a progression in the use of logical operations in the solution of science tasks. In the early part of concrete operational stage, pupils may categorize and separate variables. In the later part of this stage, the pupils use logical multiplication operations and compensation operations on the same phenomena. As they enter into the formal operations stage, adolescents begin to use proportions, probability ratios, and correlational relationships. Research results of Piaget and Inhelder indicate that an individual's inquity strategy and structural organization of concepts depend upon the types of logical operations that are available. Acquisition of more complex logical operations becomes dependent upon the availability and efficiency of component operation. If

component operation can not be efficiently used then the development of the more complex logical operations will be delayed.

Greenbowe et al. (1981) maintain that few theoretical constructs from psychology or education have captured the fancy of science educators more than Piaget's theory of intellectual development and the concept of formal-operational reasoning has stimulated considerable interest in science education during the past decade. Piaget is more acceptable to physics discipline, since its very elements parallel the mechanics of scientific discovery and scientific inquiry (Griffiths, 1976; Liberman and Hudson, 1979). Operational reasoning such as control of variables, combinatorial reasoning, propositional reasoning and proportional reasoning denote kinds of thinking that scientists find valuable. Inhelder and Piaget's descriptions of children's analyses of angles of incidence and reflection, floating bodies, bending rods, oscillation of pendulum, falling bodies on an inclined plane, combination of chemical bodies and equilibrium in a balance, certainly demonstrate the logic that Piaget calls formal-operations is used in science. The relationship between Piaget's theory and scientific inquiry is so close that many have referred to Piaget's formal-operations as "scientific reasoning" (Greenbowe et al., 1981). The acquisition of formal-operational schemata is of considerable importance to science students. Proportions are the most ubiquitous mathematical tools of any introductory science course. Indeed, many physics concepts, such as density, acceleration, gravitational force, etc. are, in effect, names given to proportional relationships. Students' ability to comprehend and to effectively use the proportions, therefore, should be a major concern to science educators. Combinatorial reasoning is required for comprehension of Mendelian genetics. Correlations represent the cornerstone of much of the descriptive, investigative work of scientists and educationists, e.g., is there a relationship between food habits and diabetes, intelligence and academic achievement, or pressure and volume of a gas? In short, the formal-operational schemata not only play a role in students' understanding of

important science concepts, but also play a major role in the process of scientific investigation (Lawson, Karplus and Adi, 1978).

A few researches have claimed that there is a high degree of relevance between Piaget's theory of cognitive development, and materials and teaching methods of physics curricula. These articles stress two main points; first, that there are certain ascertainable developmental differences among students when Piaget's measures are employed, and second that such differences warrant new approaches to curriculum, teaching methods, and evaluation in the line of Piagetian theory (Cohen, 1978). Any attempt to adapt curricula to the developmental levels of the intended population, must be applauded as an important step toward improving the quality of our educational system, particularly if it is combined with the appropriate methodological education of our teachers. Understanding to concepts needs to be matched with the hierarchy of concept formation. Abstract concepts are to be taught through a methodical approach which will incorporate the consideration of searching and presenting perceptible examples along with the creation of pseudo-examples through two-dimensional or three-dimensional medium for effective communication for the students of concrete-operational stage and for the students who are at the transition level, between concrete and formal—operational stages.

Brown et al. (1977) maintain that the teaching of science is generally considered to be a systematic attempt for communication between a scientific and nonscientific group. The teaching of science should involve more than the mere transmission of factual information. Indeed, people would agree that a more important goal is teaching students to be able to use basic facts and concepts flexibly so that they can deal with new situations, predict various consequences, and solve problems. In a science such as physics, important relations constitute basic building blocks which can be used to account for observations and to solve various problems (Reif et al., 1976). These relations include definitions (such as the defi-

nition $\vec{a}=d\vec{v}/dt$ of acceleration) and laws (such as Newton's equation of motion $\vec{F}= m\,\vec{a}$). Relations like this occupy a large part of higher secondary physics course. Clement (1982) has discussed difficulties in understanding conceptual primitives presented at the qualitative level. Conceptual primitives include :

(i) key concepts such as mass, acceleration, momentum, couple, energy, charge, potential difference, etc., and

(ii) fundamental principles and models such as Newton's laws, conservation laws, the atomic model, etc. Understanding of conceptual primitives is a basic prerequisite for higher order concepts. Majority of science concepts at high school and college level are abstract (Lawson and Renner, 1975) which do not have perceptible examples or attributes or both (Cantu and Herron, 1978).

Brady (1970) points out that an essential component of any successful teaching situation is an awareness by the teacher of a pupil's level of comprehension so that the teaching is meaningful. Discussing physics teaching: Griffiths (1976) suggested that the teaching of physics often inhibits the intellectual development of students. To quote him,

> "A necessary condition for effectively teaching physics is that the students have the capability of operating at the cognitive level that is matched with the logical structure that produced the discipline. Recent research indicates that a majority of students are not demonstrating this capacity. The analysis of the performance of students 'learning' physics without the necessary cognitive development demonstrates behavior that hinders their intellectual growth" (p. 81).

Since majority of science concepts are abstract and require formal thought for their understanding, it becomes imperative

to know the level of cognitive development of these secondary and higher secondary students, i.e., what proportion of students are at the concrete operational and formal-operational stages. This will help to assess with what effectiveness different physics concepts can be taught to them. Such information could help to adapt course contents, goals and teaching methods to fit the reasoning level of students.

It is reasonable to believe that formal-operational students, capable of hypothetical thought, will attain physics concepts better than concrete-operational students who reason from concrete objects and work with logical operations that refer to empirical reality, and naturally science achievement and understanding of science concepts will be related to student's operational reasoning ability. A large number of studies reported that formal thinkers outperform concrete thinkers (Sheehan, 1970; Lawson and Renner, 1975; Cantu and Herron, 1978; Howe and Early, 1979; Barber, 1980; Nurrenbern, 1980; Bass and Maddux, 1982; Yeany and Porter, 1983; McKenzie, 1984; Milka, 1984; Peabody, 1984; Abraham and Renner, 1986) and science achievement and understanding of science concepts are related to students' operational reasoning ability (Raven et al., 1974; Raven and Polanski, 1974; Sayre and Ball, 1975; Wheeler and Kass, 1978: Liberman and Hudson, 1979: McBridge and Chiarpetta, 1978; Walker, 1979 ; Contessa, 1980 ; Johnston, 1980 ; Piburn, 1980 ; Ward and Herron, 1980 ; Sandhu, 1980 ; Gapel and Sherwood, 1981a ; Thorton and Fuller, 1981 ; Za'rour and Gholam, 1981 ; Jacob, 1982 ; Lawson, 1982 b ; Payne, 1982 ; Staver and Halsted, 1982 ; McMeen, 1983 ; Durr, 1984 ; Farrell and Farmer, 1985 : Tobin, 1986). As a consequence of these researches several writers have emphasized the need to modify objectives, contents, and teaching methods according to the level of cognitive development of learners (Lawson and Renner, 1975 ; Chiappetta, 1976 ; Shayer, 1978). Some writers have also urged that the development of formal-operational reasoning should be a major priority in science education (McKinnon and Renner, 1971 ; DeCarcer, Gabel and Staver, 1978 ; Lawson, 1982a). Concrete-operational students when confronted with

problems requiring formal-operational thought are left with few choices. They can either turn to some other activity, or memorize an algorithm that works sometimes (Ward and Herron, 1980). Many formal-operational students may be forced with the same choices if they fail to see how their existent formal schemes can be applied to the new subject matter (Ausubel, 1964 ; Piaget, 1972 ; Chiappetta, 1976. Although, cognitive development is hypothesized to be an important factor for science achievement, some studies revealed that no significant relationship was found between formal-operational reasoning and science achievement and students of differing cognitive levels achieved similarly Champagne et al., 1979 ; Cole, 1979 ; Collins, 1979 ; Dallan, 1979 ; Grant, 1979 ; Kishta, 1979 ; Stopler, 1979 ; Hartford, 1980 ; Wilson and Wilson, 1984a, 1984b). However, a thorough search by the researcher did not reveal adequate number of studies in Indian condition in this area. Some systematic studies in India pertaining to this domain have been conducted, and are still in progress at Regional College of Education, Ajmer, under the guidance of Prof. N. Vaidya, among which Sandhu (1980), Jacob (1982), Jain (1982) and Mathur (1982) found significant relationship between Piagetian reasoning and achievement. In addition to science achievement, problem—solving behaviour in physics was reported to be significantly related with intellectual development by Jain (1982).

Inconsistency in findings related to operational reasoning ability and science achievement creates the need of further investigation in this domain with altered design and tool for measuring physics achievement. To make measurement of achievement in physics easier and yet effective, systematic. less time consuming with full coverage for individual concepts in physics, concept attainment tests in physics based on the method developed at Research and Development Center for Cognitive Learning, Wisconsin Universlty, Wisconsin were thought to be more useful in this study. This might lead to the more precise measurement of physics concept attainment and help in bringing more precision to the study of relation-

ship between operational reasoning and physics achievement in the form of the relationship between operational reasoning and concept attainment in physics.

To find out a relationship between operational reasoning and concept attainment does not cover the whole problem area. In case a significant relationship is obtained between operational reasoning and physics concept attainment, a question arises whether this relationship is due to confounding effect of other variables or not ? Although cognitive development is an important factor for concept attainment, studies suggest that other important factors affect achievement and understanding of concepts. Among these variables one is teaching methods (Hewson, 1981 : Hewson and Hewson, 1981 ; Porter, 1981 : Saunders and Shepardson, 1984 ; Koul and Bhadwal, 1986). Achievement motive is another important variable affecting achievement and concept attainment (Pandey, 1981 : Gandhi, 1982 ; Rai, 1984 ; Warren, 1984). Besides these, another important variable affecting concept attainment is general mental ability (Cole, 1979 ; Nussbaum, 1979) which is different from Piaget's concept of intelligence as may be clear from following paragraphs.

Mental testing tradition, which focuses on IQ test data, has been largely concerned with quantitative questions, viz., age-related improvements on mental test performance and the extent to which mental test performance predicts external criteria such as achievement. Piaget's theory emphasizes qualitative reorganizations of the structures that govern intelligence rather than incremental changes in cognitive content. It is usually called a discontinuity theory. Theories derived from the mental test tradition, which emphasize age-related changes in cognitive content, are called continuity theories (Brainerd, 1978). In learning approaches, it is traditionally assumed that intelligent behaviour starts out as random and unorganized affair and organizational capabilities are acquired through the medium of infant and childhood experiences. For Piaget, organization is a guiding force from the beginning and, therefore, presumably is an innate feature of intelligence. To summarize, it can be said that while learning approaches

postulate that organization gradually is imposed on intelligence by the environment, Piaget believes that organization is always present, although the specific structures through which it is manifested, change.

Piaget expects tests based on his theory to theoretically and empirically define basic and general thought processes and assess their level "better" than do psychometric tests. Psychometric tests assess only the products of thought while Piagetian tests get the very process of cognition (Kohlberg and DeVries, 1974). Piaget (Modgil and Modgil, 1976) has further elaborated his views that traditional tests are concerned with quantitative measures of behaviour and do not penetrate into the actual qualitative operational mechanism which govern the behaviour. Conceptual differences between Piagetian and psychometric conceptions of intelligence have been outlined by Elkind (1969) who maintained that differences arise from the unique ways that each conception views intelligence and that they focus on different aspects of intelligent behaviour. He commented on differences in respect of "(a) the type of genetic causality they presuppose; (b) the description of mental growth they provide; and (c) the contributions of nature and nurture which they assess". Whimby (1974) also states.

> "IQ tests donot measure innate intellectual capacity, but rather a group of learned skills that can be taught in the classroom or in the home. Specifically, they measure the learned ability to form relationships with verbal or symbolic concepts" (p. 50).

The discussion shows that Piagetian reasoning tasks involve abilities separate from those measured by standard tests of intelligence and achievement. Lawson tried to answer the question whether the relationship between Piagetian reasoning ability and science achievement is due to confounding effect of other variables by partialling out the effect of cognitive style (1980) and fluid intelligence (1982b). It seems to be reasonable to say from above discussion that there is a need to see the effect of operational reasoning on physics concept attainment

after partialling out the effect of achievement motive and general intelligence.

During the last few years there has been considerable interest to determine factors which have predictive and correlational validity for physics achievement and most of the effort centred around formal-operational reasoning, as defined by Piaget, and mathematical skills. In this study, it has been decided to see if the combined effect of operational reasoning ability, general intelligence and achievement motive could provide higher correlations with performance on physics concept attainment tests than either measure alone. The question before investigator was whether or not the various measures, e.g., operational reasoning, general intelligence and achievement motive, were tapping different mental structures and if so, what is the relative importance of these measures in concept attainment in physics.

In view of the contrast in findings regarding the effect of cognitive development on science achievement and the fact that certain other variables, e.g., previous knowledge (Anderson, 1974 ; McVey, 1981 ; Wilson, 1982 ; Rai, 1984), teaching methods, general intelligence and achievement motive also affect science achievement, a need was also felt to investigate the difference in concept attainment in physics, if any, of concrete-and formal-operational students by holding constant the effect of teaching method, previous knowledge, general intelligence and achievement motive.

Till the day, very few researches are traceable about the interaction in the field of cognitive development. Among the studies that came into the knowledge of the investigator which investigated the interactive effect between cognitive development and instructional treatment are of Gabel and Sherwood (1980) on chemistry achievement, Chiappetta and Russell (1982) on earth science achievement and Crenshaw (1983) on biology achievement, Abraham and Ranner (1986) studied interaction effect between class level and developmental level on the concept achievement test in chemistry whereas Staver

and Halsted (1985) looked into the three-way interaction of Piagetian reasoning, model usage, and sex type on achievement of high school chemistry students. These studies did not touch the problem area of interaction of cognitive developmental level and achievement motive. So, the present investigator felt an additional need to study the interaction of cognitive developmental level and achievement motive on concept attainment in physics by controlling teaching method and previous knowledge.

1.5 Statement of the problem

The present problem specifically reads as follows :

"OPERATIONAL REASONING AND CONCEPT ATTAINMENT IN PHYSICS".

1.6 Objectives of the study

The objectives of the present study have been set as follows :

Major Objectives :

(i) To study the distribution of Piagetian developmental stages among XI-grade science students.

(ii) To study the relationship of operational reasoning and logical thinking with concept attainment of XI-grade students in Physics.

(iii) To compare the concept attainment in Physics of XI-grade students at concrete—and formal-operational stages of cognitive development.

(iv) To study the combined and relative contribution of logical thinking, general intelligence and achievement motive towards concept attainment of XI-grade students in Physics.

(v) To study the combined and relative contribution of different aspects of operational reasoning, general intelligence and achievement motive towards concept attainment of XI-grade students in Physics.

(vi) To find out the interaction effect of achievement motive and stages of cognitive development on concept attainment of XI-grade students in Physics.

Subsidiary Objectives

(i) To adapt Longet's (1962, 1965) paper-pencil test of logical thinking for the population of high school and higher secondary science students of Varanasi city, in Hindi.

(ii) To study differences in operational reasoning and logical thinking of XI-grade male and female science students.

1.7 Hypotheses

To achieve the objectives of the study and arrive at worthwhile conclusions it becomes an imperative on the part of the researcher to formulate tentative hypotheses before hand. A hypothesis, which is tentative expectation about relationship between variables, can be tested in various ways. Here in this investigation, null hypotheses have been formulated as follows :

Ho1 : Different aspects of operational reasoning (class-inclusion, propositional reasoning, proportional reasoning, combinatorial reasoning) and logical thinking do not correlate significantly with (a) total concept attainment scores in Physics, (b) concept attainment scores in concept Force ; (c) concept attainment scores in concept Couple ; (d) concept attainment scores in concept Total Internal Reflection ; (e) concept attainment scores in concept Atom.

Ho2 : Students at concrete-operational stage and those at formal-operational stage do not differ significantly in their (a) total concept attainment scores in Physics; (b) concept attainment scores in concept Force ; (c) concept attainment scores in concept Couple ; (d) concept attainment scores in concept

Total Internal Reflection ; (e) concept attainment scores in concept Atom.

Ho3 : Logical thinking, general intelligence and achievement motive do not account for significant amount of variance towards (a) total concept attainment scores in Pysics ; (b) concept attainment scores in concept Force ; (c) concept attainment scores in concept Couple ; (d) concept attainment scores in concept Total Internal Reflection ; (e) concept attainment scores in concept Atom.

Ho4 : Different aspects of operational reasoning (class-inclusion, propositional reasoning, proportional reasoning, combinatorial reasoning), general intelligence and achievement motive do not account for significant amount of variance towards (a) total concept attainment scrores in Physics ; (b) concept attainment scores in concept Force ; (c) concept attainment scores in concept Couple; (d) concept attainment scores in concept Total Internal Reflection ; (e) concept attainment scores in concept Atom.

Ho5 : There is no significant interaction effects of achievement motive and stages of cognitive development on (a) total concept attainment scores in Physics : (b) concept attainment scores in concept Force ; (c) concept attainment scores in concept Couple ; (d) concept attainment scores in concept Total Internal Reflection ; (e) concept attainment scores in concept Atom.

Ho6 : There is no significant difference in the (a) Class-inclusion ; (b) Propositional reasoning ; (c) Proportional reasoning ; (d) Combinatorial reasoning ; (e) Logical thinking of XI-grade male and female science students.

1.8 Assumptions

In the present investigation it was assumed that :

(i) Different aspects of operational reasoning can effectively be measured by subtests of Tarkik

Chintan Parikshan (TCP), a paper-pencil test of Piagetian reasoning,

(ii) Logical thinking can effectively be measured by total score on TCP.

(iii) Concrete-operational and formal-operational students can be identified by their scores on TCP.

(iv) Previous knowledge of students in Physics can be measured by the administration of concept attainment tests in Physics prior to teaching of concepts.

1.9 Delimitations

(i) This investigation was confined only to the Varanasi City of Uttar Pradesh and comprised of 240 male and female XI-grade science students enrolled in different intermediate colleges.

(ii) The classification of students was limited to only two Piagetian cognitive levels—concrete—and formal—operational—as determined by TCP.

(iii) Only four concepts of Physics were selected for the present investigation.

1.10 Definition of Terms

Concept : All categorizing activity involves identifying and placing events into classes on the basis of certain criteria and ignoring others. The environment is so diverse and we are required to discriminate so many objects and aspects of objects. "Were we to utilize fully our capacity for registering the differences in things and respond to each event encountered as unique, we would soon be overwhelmed by the complexity of our environment", asserted Bruner et al., (1962, p. 2). They further added that to cope with the environment "we engage in the process of categorizing, which means that we 'render' discriminately different things equivalent . . . responding to them in terms of their class membership rather than their uniqueness" (p. 12). In other words, we invent categories and form concepts which are the key building blocks for the structure of knowledge of various academic disciplines and are

the critical components of an individual's cognitive structure. One is almost baffled at the number and variations of the definitions of the concept as he enters the field of concept learning. Vaidya (1980) maintains that the term is easily understood than formally described for suiting all occasions and objectives. It is so because it is seen differently by different persons ; Laymen, teachers, method specialists, educators, scientists, mathematicians, logicians and philosophers. Martorella's (1977) compilation of a large number of definitions from the literature suggests the difference of opinion that exists concerning the properties of concepts. Klausmeier et al. (1974) suggested three reasons for variations in the definitions : the number of entities called concepts is very large ; there are real differences in the nature of concepts both across and within disciplines ; and an individual's concept of the same thing or classes of things changes markedly with increasing maturation and learning. Some definitions of concepts are as follows :

"A concept is a generalized and abstract symbol ; it is the sum total of all our knowledge of a particular class of subjects . . . In short, a concept is a condensation of experience" (Viaud, 1960, pp. 75-76).

According to George (1962, p. 260), a concept may be thought of as "the common element shared by an array of objects or the relationship between the constituents or parts of a process".

Taba (1965, p. 465) stated that, "the basic concepts are essentially high level abstractions expressed in verbal cues and labels".

Klausmeier and Ripple (1971, p. 402) define concept as ". . . a mental construct, or abstraction, characterized by psychological meaningfulness, structure, and transferability that enable the individual to do the following : (1) cognize things and events as belonging to the same class and as different from things and events belonging to other classes :

(2) cognize other related superordinate, coordinate, and subordinate concepts in a hierarchy ; (3) acquire principles and solve problems involving the concept ; (4) learn other concepts of the same difficulty level in less time".

According to Klausmeier (1977), "Concepts can be thought of as information about objects, events, and processes that allow us to (i) differentiate various things or classes, (ii) know relationships between objects, and (iii) generalize about events, things, and processes".

Tennyson and Park (1980, p. 56) assume concept to be "a set of specific objects, symbols, or events which share common characteristics (critical attributes) and can be referenced by a particular name or symbol".

Asha Pandey (1981, p. 11) after reviewing definitions of concept, compiled three common properties of concepts as follows :

1. A concept is an inferred mental process.
2. The learning of a concept requires discrimination of stimulus objects (distinguishing 'positive' and 'negative' instances).
3. The performance which shows that a concept has been learned consists of learner being able to place an object in a class.

Piagetian researchers (e.g., Flavell, 1970, 1971, 1972) use stage and logico-mathematical constructs to define concepts in reference to general development period in question and in the general logical groupment of cognitive structures.

Novak (1966) while writing about concepts, pointed out that many different terms are found in literature for concepts of science, such as :

(i) concept,
(ii) conceptual scheme,

(iii) theme,

(iv) organizational thread,

(v) major generalization,

(vi) major concept,

(vii) fundamental idea, and

(viii) major principle.

According to him, what most writers in the area of science concepts do is to provide an operational definition of the term and proceed.

Operational definition : Concept is the ordered information about the properties of one or more things—objects, events or process that enable any particular thing or class of things to be differentiated from other things or classes of things.

Concept Attainment : Research in the field of concept development has been conceived under two major areas (Eysenck and Wilson, 1976), namely :

1. Research on the development of basic concept in children referred to as "concept formation" studies, and
2. Research on the development of new concept in adults, referred to as "concept attainment" studies.

Concept attainment is the process by which mature individuals arrive at concepts in particular instances by using already acquired cognitive skills (Bruner et al., 1962). Whereas concept formation is the developmental process of acquiring the cognitive skills necessary to thinking and to attaining concepts. Joyce and Weil (1985) have made distinction between concept attainment and concept formation. In concept attainment the concept already exists. Concept formation, in contrast, is the act by which new categories are formed; it is an act of invention. Ausubel (Klausmeier et al., 1974 ; pp. 20-21) also maintain that,

> "Many concepts are attained . . . through being given the names of concepts, verbal definitions, and verbal examples, but no actual instances of the concepts. Ausubel has designated this kind of learning "concept assimilation", an example of meaningful reception learning, to contrast it with "concept formation", an example of meaningful discovery learning".

According to Bruner et al. (1962) categorizing activity actually has two components, the act of 'concept formation' and the act of 'concept attainment'. They maintain that concept formation is the first step toward concept attainment. Joyce and Weil (1985) have argued that the distinction between concept formation and concept attainment, though subtle, is important because :

(i) the purpose and emphasis of these two forms of categorizing behaviour are different ;

(ii) the steps of the two thinking processes are not the same ; and

(iii) the two mental processes require different teaching processes. Concept formation refers to the act by which classes are constructed, whereas concept attainment is the process of learning what features of the environment are relevant for grouping events into externally defined classes. Bruner and his colleagues (1962, p. 33) define concept attainment as, "the search for and listing of attributes that can be used to distinguish exemplars from non-exemplars of various categories".

Archer (1966) defines concept learning as a term which applies to any situation in which a subject learns to make an identifying response to members of a set of completely identical stimuli. He added a further restriction that the subject must apply the classification rule which is to identify a stimulus as belonging to a group. He noted that if there is any distnictive feature about concepts in general, it is that they vary

widely in terms of complexity. Tennyson and Park (1980, p. 56) define concept learning as, "the identification of concept attributes which can be generalized to newly encountered examples and discriminate examples from non-examples.

There are certain fundamental concepts which are something that need not acquiring but are acquired slowly and in successive stages. Piaget's investigations show that the concepts of an enduring object, conservation (length, quantity, etc.), proportion, combination, etc. are acquired in successive stages.

Most concepts in the domain of science (Physics, Chemistry, Biology, etc.) are actually combinations of fundamental concepts or thought processes that can be identified in the cognitive development research of Piaget. For example, in classical mechanics, time is taken as a fundamental notion and velocity as something derived from it. This concept underlies all motion studies. Similarly, unless one has the understanding of the concept of proportionality, he can not attain many concepts of physics, such as acceleration, force, gravitational force, etc.

Operational definition : Concept attainment is the search for and listing of attributes that can be used to distinguish exemplars from non-exemplars of various categories. Concept attainment, in the present context, is conceived as the correct responses to various aspects of the concept under question. More the number of correct responses, higher the concept attainment.

Total Concept Attainment : Total concept attainment, in the present study, is defined as the sum of correct responses on all the four concept attainment tests. viz., Force, Couple, Total Internal Reflection and Atom.

General Intelligence : It is conceived as ability to use words and numbers with facility, to reason and to comprehend in-

structions. In the present case it was measured by Joshi's 'Test of General Mental Ability'.

Achievement Motive : This is defined as the tendency to strive for success in competition against some standard of excellence (McClelland, 1961). However, in the present study the achievement motive has been considered as a multidimensional attribute which may be indicated by showing persistence, personal responsibility, moderate-low risk taking, upward mobility, choice of experts as partners, realistic goal-orientation, future-time perspectives, dynamic perception of time, achievement behaviour and recognition behaviour. It has been expressed here in terms of total achievement motive scores formed by summating the scores on these characteristics when measured by Gandhi and Srivastava's 'Achievement Motive Inventory'.

Stages : They are the period of development characterized by certain general mental structures.

Cognitive Development : It is the level of cognitive development defined by Piaget's stages. The student population classified in terms of the scope of this investigation will have their cognitive level determined through the use of the Tarkik Chintan Parikshan (TCP). From the results obtained through the administration of this test, students will be defined as concrete—or formal—operational when making reference to Piagetian cognitive levels.

Concrete Operational Stage : It is a stage of mental development where the individual performs such logical operations as adding, subtracting, seriating, classifying, numbering and reversing.

Formal-Operational Stage : It is a stage of mental development where the individual shows hypothetical, propositional, and reflective thinking.

Logical Thinking : It is the mental action that the child learns to manipulate data mentally and deal with several

variables. They are able to associate, reverse, and combine information. This has been measured, in the present study, by total score on TCP.

Operation : It is a mentally represented action that obeys certain rules of reversibility and can be integrated with other actions also possessing this feature of reversibility.

Operational reasoning : It is the reasoning that develops during concrete—and formal-operational stages. In the present study operational reasoning has been taken to mean reasoning used to solve class-inclusion, proposition proportion and combination problems. These have been considered as different aspects of operational reasoning and are being measured by subtests of TCP in this research.

Class-inclusion : It is an understanding that a class can exist within another, more comprehensive class. By this concrete-operational ability, (i) the part and whole can be thought about independently, and (ii) multiple classification is possible.

Propositional reasoning : This refers to making inferences from given statements without regard to factual basis of statements. It involves series of hypotheses in proposition form and making inferences with the "if—then" form of reasoning.

Proportional reasoning : This refers to making inferences from data under conditions of constant ratio.

Combinational reasoning : It is a cognitive strategy where children are to employ "combinatorial analysis". This means they will use all possible combinations or factors related to a problem in solving it.

2

Review of Related Literature

Research literatures on cognitive development show that reasearches conducted outside Geneva are more with concrete-operational stage than the formal-operational stage. A majority of those researches concentrated on the determination of various stages of the development at which subjects had been operating. During the last ten to fifteen years formal-operational reasoning has aroused considerable interest among science educators and a large number of research studies have appeared in science education journals. Relevant research studies belonging to different areas, which conform to the objectives of the present study, have been presented under following heads :

(i) Studies related to distribution of different congnitive stages.

(ii) Studies related to sex difference in operational reasoning and cognitive development.

(iii) Studies related to operational reasoning, cognitive development and science achievement.

(iv) Studies related to interaction effect of cognitive development and other variables on science achievement.

(v) Studies on relationship of IQ and Piagetian tasks.

2.1 Studies Related to Distribution of Different Cognitive Stages

According to Piaget's theory, the formal stage of intellectual development starts at 11-12 years of age and the individual becomes fully formal at the age of 15-16 years. This led to believe that most individuals are formal-operational thinkers by 15 or 16 years of age. But, Lovell (1961), who performed many Piagetian studies with English students, discovered that some of the subjects in his studies were not formal-operational by the age of 15. He suspected that the subjects with whom Piaget worked in Geneva were rather better students, thus providing Piaget with adolescents who at 15 and 16 years of age were demonstrating formal reasoning. Piaget (1972) afterwards came to realize that the results he found with 11-15 years old in Geneva, could not be generalized to adolescent population, since the subjects were taken from better schools in Geneva. Piaget (1964) also stated earlier that the average ages at which these stages appear varies a great deal from one society to another, although the ordering of these stages was constant and had been found in all societies studied.

Vaidya (1964) using a questionnaire approach as well as interview approach, found that adolescent pupils of two schools in central London were in a position to state hypotheses but most of them were not in a position to test them. They did not, contrary to Piaget, exhaust all possibilities. In another study, Vaidya (1975) while studying the Growth of Logical Thinking in Science during Adolescence, found that adolescent pupils were in a position to set up hypotheses, but were not in a position to test them. Higgings-Trenk and Gaite (1971) concluded from their study with American subjects "that normal adolescents are unlikely to reach the level of formal thinking until their late teens or early twenties if they reach it at all". Kohlberg and Gilligan (1971) stated that all normal children reach the concrete level but do not necessarily reach the formal operational level of reasoning. Howe (1974) reported that it would be a mistake to assume that even upper-level secondary

students, except very ables, have access to formal-operations for solution of most problems.

Almost all the studies which the researcher came across, except Mecke and Mecke (1971), reported that a large portion of secondary school students did not function at the formal-operational level. Chiappetta (1976) reviewed the studies which employed at least three (and usually more) Piagetian type tasks and where the researcher (s) presented the tasks in a personal interview format to subjects. He concluded "that most adolescents and young adults (over 85% of this population) in U.S.A. do not appear to be at the formal-operational level of intellectual development " Mecke and Mecke (1971) were the only investigators, as the present investigator could trace out, who found all in a sample of 15-years-old to use formal operations. However, they determined that a subject used formal operations if he simply used a systematic approach to eliminate the irrelevant variables in Piaget's pendulum problem. Inhelder and Piaget (1958) considered a systematic approach to be necessary, but not sufficient condition for formal operations. A person at the formal-operational level must be able to investigate the variables and then explain how they interact. Thus, Mecke and Mecke's research did not really contradict other studies. It did emphasize the need for clear, workable standards for further research on formal operations The task used, the subject's previous experience, and the definition of formal operations, all effect the proportion of subjects exhibiting formal operations. The studies reviewed here involve junior high school, high school, and college students.

Dulit (1972) found that only 25-33% of normal adolescents, aged 14-17, and 60% of the gifted 16- and 17- years old exhibited formal operations when they tried to solve some of the Piaget's experiments. Renner and Stafford (1972) assessed the developmental level of 298 junior high school students (grades 7, 8 and 9) and 290 students in grades 10, 11 and 12, living in various parts of Oklahoma, by using six Piagetian tasks. Their results showed that among junior high school

students 77% were concrete-operational, 14% were post-concrete-operational, and 6% were formal-operational. Among senior high school students 66% were at the concrete-operational stage, 17% at the post-concrete-operational stage, and 14% at the formal-operational stage. Mishra (1973) investigated the role of hypotheses in problem-solving among tenth grade science students and found that many adolescent pupils experienced difficulty in testing hypotheses.

Lawson (1974) using six Piagetian type tasks in a study of the relationship between concrete—and formal—operational science subject matter and the cognitive developmental level of the learner, assessed the developmental stages of 51 biology, 5o chemistry and 33 physics students from a high school. His results showed that 64.8% of the biology, 22% of the chemistry, and 36.3% of the physics subjects were at the concrete-operational level, while 35.2% of the biology, 78% of the chemistry, and 63.7% of the physics students were at the formal-operational level. Lawson, in another study with Blake, on 68 high school biology students (age range 14 years 7 months to 17 years 10 months) showed that 47% students were concrete-operational and 53% were formal-operational (Lawson and Blake, 1976b). Nordland et al. (1974) studied the reasoning ability of 96 randomly selected seventh grade students (age range 11.7 years to 12.6 years) from a predominantly Black and Spanish-American urban junior high school by using ten Piagetian tasks. The results of the interview indicated that 83.4% of the students were at the formal-operational level.

Bady (1977) assessed the ability of ninth grade, eleventh grade and college students to identify correlations in data and to test hypotheses. His results showed a 40% success rate by college students, 15% by eleventh grade and 5% for ninth grade students. Lawson and Nordland (1977) reported that majority of high school biology students performed below the formal-operational level on weight and volume conservation tasks. High school biology students, college freshmen from introductory physics and college seniors majoring in

science were administered two Piagetian tasks (chemical liquids and inclined plane) by Kolodiy (1977). The researcher reported that scores for high school and college freshmen were nearly equal (35% and 32% formal ; 50% and 60% transitional ; and 15% and 8% concrete), and significantly different from the college senior sample (64% formal ; 28% transitional ; and 8% concrete). Wheeler and Kass (1977) investigated the proportional reasoning abilities among tenth grade chemistry students and found that 22% of the students were late formal, 27% early formal and 29% concrete.

Upadhyay (1978), in a study of tenth grade science students, reported that majority of the fifteen years old do not operate at the formal level. About 25% of the ninth graders and 30% of the college students were reported to do the Piagetian task, without manipulating the experiment (Juraschek and Grady, 1981). A few were able to arrive at the right answer by trial and error, whereas one-half to two-thirds could not do the task. Jain (1982) administered four Piagetian tasks-metal cylinders. Bending rods, Balance and Pendulum—to 180 eleventh grade science students selected from higher secondary schools in Ajmer city. He found that only 65 students were at the formal level, 32 were at the concrete-operational stage and rest at the post concrete level. Padmini (1981) studied 200 students (100 boys and 100 girls) of Mysore city in the age range 10^+ to 14^+ and found that majority of the students were operating at the concrete level. Billeh and Khalili (1982) assessed the cognitive developmental level of eleventh grade students in Jordan. Their results showed that 17% students were at the formal operations stage and 52% at the concrete stage of mental operations.

Alport's (1983) study on 100 high school and college students (using two concrete and three formal tasks) showed that no task was passed by more than 43% of the high school and college students, and the most difficult task was passed by only 18% of the sample. Wavering et al. (1983) examined the performance of sixth, ninth, and twelfth grade students on five logical and spatial tasks. They found that only 54% of the

subjects passed the concrete-operational seriation task, less than 20% scored at the highest level of the projective space and measurement group tasks, and only 9% or less scored at the formal level on the separation and control of variables or proportional reasoning tasks. Wavering et al. (1986), in another study with the students of grades six, nine, and twelve, reported that 35% of the sixth graders, 59% of the ninth graders, and 68% of the twelfth graders completed the concrete task of seriation at the highest level, while 0, 6 and 6% performed at the highest level on the flexible rods task.

DeHernandez et al. (1984) used four Piagetian tasks-conservation of volume, separation of variables, equilibrium in the balance and combination of colourless chemical liquid—to assess the cognitive developmental level of 16-17 years old students. They found the following distribution of cognitive levels : 35% concrete-operational, 45% transitional and 20% formal-operational. Maiman (1984), in a study of 209 twelfth grade male science students in Saudi Arabia, reported 67.5% of the students to be non-formal thinkers. He recommended the re-evaluation of the existing chemistry curriculum so that it may fit the cognitive level of learners. He also recommended a special training of the high school chemistry teachers in Piagetian theory and its application in teaching-learning process. Wilson and Wilson (1984) made a population survey of high school students in Papua, New Guinea in 1980 and reported that a considerable number of students were at the transitional level.

Studies with college students and teachers also revealed similar results. McKinnon and Renner (1971) questioned whether the majority of college freshmen were mentally prepared adequately to deal with many science principles taught at the college level. Using five Piagetian type tasks they found that approximately 50% of the college freshmen in their sample were concrete-operational thinkers, 25% were in transition to formal-operational thinking, and only 25% could be clearly classified as formal-operational thinkers. To determine how many people regularly use formal operations, Karplus and Karplus (1970) used the Island problem. They found that only

40% of the group of physics teachers used formal operations to solve this problem. Juraschek (1975) studied the performance of 141 prospective elementary school teachers, 19 secondary mathematics student teachers, and 11 honours calculus students. He reported that 52% of the prospective elementary school teachers were at the concrete-operational stage, while 48% were at the formal-operational stage. Among the mathematics student teachers, only 1% was reported at the concrete level, while all of the honours calculus students were classified as formal thinkers.

Cognitive developmental level of 143 college freshmen (median age 18.6 years), randomly selected from a private university in Oklahoma, was analyzed by Lawson and Renner (1974). The results showed that 51% were at the concrete-operational stage, 27% at the post-concrete stage and 22% were at the formal-operational stage. Arons (1976) studied students in an introductory physical science course and found that not more than 25% had attained the level of formal operations; perhaps 25% were in transition between concrete and formal levels and about 5% were essentially concrete operational. Renner (1976) cited research showing that "50% of Oklahoma's entering college freshmen, and 66% of its high school seniors still occupy the concrete-operational stage of intellectual development".

Joyce (1977) and Ehindero (1977) assessed the intellectual development of prospective teachers. Joyce (1977) reported surprisingly high percentages of elementary education students in the upper range; 26% "very formal" or successful on all five tasks, 52% formal, or successful on four of the five tasks, 15% transitional or successful on three of the five tasks and 8% concrete. Ehindero (1977) reported that 68% of the prospective teachers exhibited formal thought on five Piagetian paper-and-pencil tasks.

Maloney (1981) gathered data on the Piagetian level of physics students in a large liberal arts university and found

that most were at the formal level of development. Thorton and Fuller (1981) reported that only 60 to 78% of the college students showed formal thought on proportional tasks. The distribution of cognitive levels, as reported by El-Sowygh (1982), among Saudi Arabian college students was : 15.7% at the level of formal operations, 39.5% in a transitional phase and 14.8% at the concrete stage of mental operations. Out of 420 community biology students, Dettloff (1982) estimated 9% to be at the level of formal operations.

Cognitive developmental level of medical students was assessed by Hale (1982, 1983), Hale and Witzke (1982) and these studies also showed varying proportions at different developmental levels. Hale (1982) found that only 4% of the medical students demonstrated formal operations and 96% were in the transition from concrete to formal operations. In another study of medical students, Hale and Witzke (1982) found that 57 to 91% (depending on the problem-solving case) students were able to demonstrate formal operations, with the proportion varying according to the task under study. Hale (1983) asked 59 second year medical students to solve 12 Piagetian formal-operational tasks with a purpose to describe the formal logical characteristics of those students in terms of their abilities to solve problems in four logical schema : combinatorial logic, probabilistic reasoning, propositional logic, and proportional reasoning. He found that approximately 96% of the sample were functioning at the transitional state of formal operations on all tasks. Because the sample demonstrated formal level thinking to a high degree than other samples, it was inferred that these students were adequately prepared and developed to meet challenges of their training.

Song's (1982) study showed that 40% of the prospective secondary science teachers were at the level of formal operations. Results of a study by Garnett and Tobin (1984) indicated that a large number of preservice teachers did not use formal reasoning patterns when attempting to solve problems dealing with proportional reasoning. They concluded that

teaching effectiveness would be less for teachers who are unable to use formal reasoning to fo:mulate appropriate questions and explanations in activity-oriented science lessons.

In a comprehensive overview of adolescent thought, Vaidya (1982) described his work and the findings of many studies conducted by his group and others. The findings gave evidence that concrete-operational thought dominated the adolescent years, that cognitive demand varied among the high school subjects, and that adolescent students are typically unable to test hypotheses or treat more than one variable at a time. In order to assess adolescent thought patterns and level of cognitive development, Vaidya suggested that, teachers must, like Piaget, attempt to interpret the inaccurate student responses to questions.

On the basis of the review of studies, it may safely be concluded that most adolescents and young adults do not appear to have attained the formal-operational stage of Piagetian cognitive development. A large proportion of individuals in the various age groups studied has been found to be at the concrete-operational stage.

2.2 Studies Related to Sex Difference in Operational Reasoning and Cognitive Development

Studies related to sex difference in cognitive development reveal conflicting results with more results favouring males. Lewis (1972), in a study on students from seventh to twelfth grades, reported sex differences favouring males. In a study of relationship between gender, field-dependence and formal thought, with samples drawn from junior high schools, high schools and colleges, Piburn (1977) found that males were more successful on two of the four proportionality tasks, and thus the total for that schema, and subsequently for the overall tasks. However, no significant differences were found between saxes on the performance of the five combinatorial tasks or three correlational/probability tasks. Sex differences,

Piburn (1977) concluded, "are restricted to very specific abilities, and cannot be explained away as the result of some other factor". In another study Piburn (1980), on the basis of clinical interviews of grade eleven students from suburban New Zealand schools, concluded that males achieved significantly better scores than females on the shadows task. Brown (1979) found that boys did better than girls in the ability to use proportionality concepts. Sandhu (1980) in a study of students in the age-group 11^{+} to 15^{+} found that boys performed either equal or better than girls on the Piaget-type tasks at the respective age levels. Marek (1981) found that the cognitive developmental level of men is higher than women. Hofstein and Mandler (1985), using Lawsons' test on high school Israeli students, reported that boys performed significantly better than girls on displaced volume, probability, two proportional reasoning and one combinatorial reasoning and one controlling variables item but not on other reasoning items. Significant gender difference in favour of male students was reported by Farrell and Farmer (1985) in first order direct proportional reasoning. They did not found any gender difference in multiple proportional reasoning.

Graybill (1974) reported girls to differ from boys at point from which they started developing logical thinking abilities. The study reported that boys began to score at the formal level tasks at 13 years of age while the girls lagged behind. Boys and girls began to show differences in logical thinking ability at about 11 years of age. Shayer and Wylam (1978) studied a representative sample of nine to sixteen years old British children and found that formal-operational thinking showed no increase for girls after 14 years. while the boys continued for a year further. Girls' performances were substantially lower on a test of spatial relationships, and on a test of volume and density, throughout the age-range of 9 to 16. De-Hernandez, Marek and Renner's (1914) study revealed that :

(i) males demonstrate a higher level of intellectual development than females,

(ii) males mature intellectually earlier than females, and

(iii) there appear to be factors other than age and gender that are related to development of formal-operational reasoning.

Gann (1980), using a sample of fourth grade students and Treagust (1980), using sample from eight, ten, and twelve grades, found significant sex differences favouring male students. DeLuca's (1981) study, across ages nine to eighteen, indicated that deviation from Piagetian stages was influenced by gender and the type of the task. Doody (1981) remarked that the poorer performance of females in spatial ability and science was due to a deficit in cognitive operational ability rather than in perceptual or imagery abilities. Durr (1984), and Walkotz aud Yeany (1984) reported that females, on the the average, have a slightly lower level of cognitive development.

Abovementioned studies showed that sex difference in logical thinking exists, favouring males. At the same time, quite a number of studies are also available contradicting the findings of sex difference in cognitive development and operational reasoning.

Saarni (1973), and Maccoby and Jacklin (1974) found no significant gender differences in their investigations. Rajput (1974) studied the schema of proportionality among adolescent pupils and reported that boys and girls perform equally well. Waite's (1975) study indicated no significant relationships between ability to perform on the Piagetian type tasks and sex. No gender related difference was found in cognitive development by DeLuca (1979) and Mali (1979) for elementary school students. Studies of Kishta (1979) and Ehindero (1982), on Jordanian and Nigerian high school students, respectively, did not reveal any sex difference in cognitive development. Hayes (1979), also did not find significant difference in propositional reasoning between boys and girls. Okeke and Wood-Robinson (1980) working with Nigerian secondary school biology pupils,

aged 16-18, found no significant gender difference on cognitive development. No sex difference on Piagetian tasks, requiring conservation of volume logic, separation and control of variables, proportional reasoning and exclusion of irrelevant variables was found by Jain (1982) for XI-grade science students. Using Longeot Test, Ahlawat and Billeh (1982) did not find any sex difference for XI grade science students. Golbeck (1986), using a sample of 64 college students, reported that college male and female students generally did not differ significantly on Piagetian spatial tasks, though they may be differentially influenced by task content. Killian (1979), also, did not find any evidence of gender-related differences in cognitive development of college students. Kelsey (1980), using six Piagetian tasks and working with students from grades seven, nine, and eleven, and Work (1984) working with seventh grade life science students reported no significant gender difference. Cohen (1984), in a study of the development of logical structures among second graders, reported that gender had no effect on the development of reasoning.

Above studies, among which some found sex difference in favour of boys and some did not find such difference on cognitive developmental level of boys and girls, aroused interest in the present researcher to repeat this type of study related to sex difference in cognitive development under Indian conditions. However, the researcher could trace out only one study (Raizada, 1981) who found that except 'ratio and proportion' girls perfoımed better than boys on all other types of Piagetian tasks.

2.3 Studies Related to Operational Reasoning, Cognitive Development and Science Achievement

There continues to be much interest in documenting the magnitude and the nature of the relationship between student performance and level of cognitive development, particularly, the association between cognitive development and academic achievement.

Sheehan (1970) studied the effectiveness of concrete and formal instructional procedures with concrete and formal-

operational students between the ages 12 years 6 months to 13 years 5 months. He hypothesized that subjects classified as formal-operational would score higher on criterion measures after formal instructional procedures than after concrete instructional procedures. However, the reverse was found to be true. Formal-operational students achieved significantly higher scores as a result of concrete instruction that from formal instruction. Further, formal-operational students achieved significantly higher scores across both instructions than concrete-operational students.

Shayer (1973) emphasized the formal-operational nature of chemistry and suggested that conceptual demands of chemistry should be considered higher than those of physics or biology at similar school levels. He strongly suggested that content requiring more than concrete-operational thinking would not be meaningful to the children of average intelligence before they are 16 years of age.

Raven (1974), after seven years of participating and co-ordinating many research studies concerned with the facilitation of logical operations in elementary and junior high school students, concluded "that the level of reasoning used for inquiry and concept acquisition by every individual is substantially below his capacity". Farrell (1969) has stated that formal-operational individuals have the capacity to use formal operations but are not compelled to do so. Individuals many time revert to earlier stages of cognitive functoning Intellectual competence below ones potential is referred as the "regression effect" (Chiappetta, 1976). Regression appears to occur when individuals are confronted with subject matter that is new to them. Individuals return to their general level of development after sufficient experience with the new subject matter The results of Lawson's (1974) study showed that the regression effect was demonstrated by students classified as formal-operational when tested on formal science concepts. Although the formal-operational subjects understood significantly more formal concepts than the concrete-operational subjects, they did not demonstrate full understanding of the majority of for-

mal concepts on which they were tested. The formal-operational thinkers demonstrated a great deal of understanding concrete concepts than that of formal concepts in science.

Lawson and Blake (1976b) classified high school biology students (average age 15 years and 5 months) by using three Piagetian tasks and a written biology examination. When cognitive development was assessed via performance on the Piagetian tasks, 53% of the students were rated at the formal-operational level. However, when the development was assessed within the context of biology, only 35% of the students were rated at the formal level. These results again demonstrated intellectual functioning at the concrete level within the context of science course material by the majority of students.

Sayre and Ball (1975), using 419 subjects from grades 7 to 12 and five interview tasks, reported that formal-operational subjects received significantly, but only moderately, higher grades than non-formal-operational students. Moreover, for grade seven (general science) and grade twelve (physics) subsamples, no relationship between developmental level and achievement was found, as Herron (1976) notes, due to the extreme proportion of formal-operationals, 8.6% and 80 7%, respectively. Sayre and Ball concluded that secondary science instruction should be structured around the developmental level of the students involved. Herron (1976) suggests two conflicting interpretations of this : Either the science curriculum needed to be restructured to eliminate the need for formal thought, or instances of formal thought should grow out of concrete experience. He suggested the latter to be more appropriate.

Lawson and Renner (1975) examined the relationship between developmental level and acquisition of concepts classified as concrete and formal. Developmental level was assessed by six individual interview tasks and understanding of concepts was tested by multiple-choice test of subject area comprehension and application (Bloom et al., 1956). Two analyses of variance showed significant differences in the relationship between developmental level and proportion of

correct responses for the concrete and formal questions, respectively. The authors conclude that : "Concrete-operational subjects are unable to develop understanding of formal concepts. Also, support is demonstrated for the other major premises of the study : Concrete-operational subjects are able to demonstrate understanding of concrete concepts, and formal-operational subjects are able to demonstrate understanding of both concrete and formal concepts".

Herron (1975) compiled a list of 16 commonly expected "concrete competencies" and contrasted each with the formal-operational extension normally required by science curriculum materials. Herron suggested that one should focus on a concrete approach to chemistry whenever possible, although he should attempt to develop formal-operational thought as well. This view was also expressed by Howe (1974), who suggested that, "teachers should not wait for students to become formal-operational (as it) may never happen". Howe also stressed the need for a concrete-operational mode for most instruction in science.

Karplus (1977) notes that some commonly taught concepts, such as chemical bond and gene demand formal-operational thought, while others, such as acid or cell, may be presented in either a formal or a concrete-operational mode. Cantu and Herron (1978) classified a group of chemistry students as concrete or formal, using the Longeot Test, a written test to assess the cog: nitive development. Concrete examples and non-examples were used for presenting three concrete concepts, while the three formal concepts were presented by concrete pseudo-examples, and non-examples, involving models, diagrams, and so forth. Immediate feedback was a feature of the instructional technique. Contrary to the hypothesis that concrete students should do as well as formal students on concrete concepts, formal students outperformed concrete students on two of the concrete concepts, as well as on all three formal concepts. Further, the pseudo-examples in concrete form aided both groups equally and significantly. In a post-hoc analysis, differences between those instructed with and without pseudo-examples were signi-

ficant for concrete students only. The authors note that concrete students will benefit more from pseudo-examples than formal students may not be generalizable, since this may depend on the difficulty of the concept. For a relatively easy concept, a formal students is likely to be successful irrespective of treatment type.

Nuss Baum (1979) studied the impact of Science Curriculum Improvement Study's "Relatively" unit on students of differing levels of cognitive development. In his sample of 44 second and third graders, he found that students who were closer to transitional stages had higher achievement. Wolfinger (1979) studied the relationship between teaching the concepts of floatation and living thing and the level of cognitive development among four to seven-years old students. She found that concrete-operational students did better than the preoperational ones. In two studies of young children (Padilla, 1979 ; Padilla and Smith, 1979), the cognitive developmental levels of the students were found to be closely associated with achievement defined as understanding of an idea and ability to accurately use the idea.

In a study of 112 junior/senior high school students, Lowell (1979) found that formal thinkers did better than concrete thinkers on a test of classification. Howe and Early (1979) found similar results when they used a criterion achievement in Intermediate Science Curriculum Studies classes. Formal students were found to outperform concrete-operational students in biology achievement (Cobern, 1979; Ehindero, 1979), chemistry achievement (Stephenson, 1979), ecology achievement (Holden, 1979) and physics achievement (Lybeck, 1979) in the studies of high school students. Hayes (1979), also, found similar results by using STEP test as the indicator of achievement. When cognitive development was described as the ability to do propositional thinking, McBridge and Chiappetta (1978) found significant correlations between it and a criterion achievement test on simple machines and structure of matter.

Liberman and Hudson (1979), in their study of 60 college students, found that concrete reasoning was a significant factor in predicting failure in physics achievement. Schroeder (1979) and Ward (1979), both obtained results which showed that formal students' achieved higher than concrete students. Walker (1979) studied 44 students in genetic course and found a significant correlation between formal reasoning ability and genetic achievement tests but relationship between cognitive development level and course grades was not found.

Ehindero (1980) reported, on the basis of data on 60 Nigerian preservice secondary science teachers, that there was no difference between formal and concrete-operationals on planning for concrete concepts. On formal concepts the formals succeeded more frequently. On performance in practical situations, formal-operationals succeeded differentially with formal concepts but demonstrated no significant difference with concrete concepts from concrete-operationals. Lawson (1980) analyzed the performance in a college biology class (n=41) for preservice elementary teachers. He provided evidence that concrete-reasoning and field-dependent subjects achieved less well than did formal-reasoning and field-independent subjects. When cognitive style was partialled out, the scores on the Reasoning Test (Lawson Test) and cumulative examination scores correlated significantly (r=0.53). The author maintained that such findings supported the wisdom of using scores on Piagetian-type test items as predictors.

The ability of concrete/formal-operational students to comprehend concrete/formal text and to express themselves in concrete/formal terms was the focus of the study by Barber (1980) which was carried on 200 first year high school students. Concrete-operational students were able to comprehend biological concepts expressed in concrete language, and were generally limited to concrete expressive language. In general, the cognitive ability of a given subject tracked across comprehension and expression ability. Lutes (1980) ascertained that students scoring high on a paper-and-pencil test of formal operations

were more successful on an Intermediate Science Curriculum Study achievement test. Piburn (1980), in a study of grade eleven students, reported that examination scores were significantly different for the formal and concrete groups. Examination scores correlated between 0.34 to 0.41 with the shadows, balance and surface development measures. Ward and Herron (1980), in a study with introductory college chemistry students, found results which showed that formal-operationals outperformed concrete-operationals on the formal items of the activity series and interaction tests, but not on chromatography items and application questions.

Johnston (1981) administred shortened form of the Longeot Test to 400 students in a non-urban junior high school and reported that correlation of these scores with DAT science scores was 0.51 and with grades was 0.23. The author inferred that achievement in the inquiry science classes at the school was related to high science achievement scores and to formal operations capacity. Shayer and Wylam (1981) learned that nine-and twelve-years old students' understanding of concepts of heat and temperature was directly related to their levels of cognitive development. Gabel and Sherwood (1981b) used four instructional interventions for teaching problem-solving to chemistry students. The result indicated that problem-solving in chemistry was dependent on students' proportional reasoning ability. Thorton and Fuller (1981), and Za'rour and Gholam (1981) reported significant relationships between level of cognitive development and student success in science courses or problem-solving.

Contessa (1980), Smith (1981), Miller (1981) and Viravaidhaya (1981) provided data to show significant relationships between student developmental level and achievement in secondary school science. Further support to these findings was provided by Glass (1981) who reported that formal cognitive skills were essential for the successful understanding of the heterotroph hypothesis in the Blue Version of BSCS. McVey (1981), in a study designed to explore the role that prior knowledge plays in the comprehension of scientific text,

revealed a positive relationship between student's prior knowledge of the concept of density and their comprehension of a written explanation of it. She further reported that formal-operational thinkers performed significantly better that concrete-operational thinkers in their free recall of major concepts, although not in the recall of generalizations or specific details.

Jain (1982) studied the problem solving behaviour in Physics among science students of class XI. His sample consisted of 180 students : 90 boys and 90 girls. The pupils were selected randomly and were of average socio-economic status and in the age group of 14^{+} to 16^{-} years. It was an Ex-post-facto research study under the descriptive method of research. The differential, correlational and factor analysis techniques were used to carry out the study. Intelligence, levels of intellectual development, reasoning patterns, problem solving ability, creativity and academic achievement were the variables of the investigation. Four Piagetian tasks—'Conservation of volume' using metal cylinder, 'Exclusion of irrelevant variables' using pendulum, 'Proportional reasoning' using the equilibrium in the balance and 'Separation and control of variables' using the bending of rods were used to measure the level of intellectual development. Ten problems in Physics, based on different reasoning patterns, were framed and standardized by the researcher to measure the problem solving ability. Major findings of the study were as follows :

The scores of the levels of intellectual development differed significantly at 1% and 5% levels of significance among the groups of successful, partially successful and unsuccessful problem solvers for most of the problems. On the scores of IQ also, these groups differed significantly for most of the problems. However, on the scores of creativity these groups differed only in two problems—creative thinking and proportional reasoning, and creative thinking and probabilistic reasoning. Problem solving ability scores differed significantly at 1% level of significance among the three groups of the levels

of intellectual development and IQ. The same result was obtained when the problem scores after providing hints were considered. The 'before' and 'after providing hint' scores for each problem showed significant difference at 5% and 1% levels of significance in the each group selected separately of the three levels of IQ, the three levels of intellectual development and the three levels of creativity. When the scores were classified under successful, partially successful problem solvers for each of the problem, no uniform pattern was observed with regard to the classification of students at the three levels of IQ, creativity and intellectual development. However, in most of the problems, higher level of intellectual development favours problem solving. The mathematical structure of the variables of the study, using Hotelling method indicated the existence of three factors—General Schematic learning, Creativity and Academic achievement in science.

Studies by Al-Mazroe (1982), Bender and Milakofsky (1982), Chiappetta and Russel (1982), Dettloff (1982), Lawson (1982b), Payne (1982), Staver and Halsted (1982), and Tobin and Capie (1982) provided evidence of a significant relationship between achievement and level of cognitive development amongs students in middle schools, high schools and colleges. Bass and Maddux (1982) found that students who functioned at the level of formal operations provided significantly better explanations following instruction than did peers functioning at the level of concrete operations. Since there were no significant differences between the groups on a test of knowledge, it seemed appropriate to attribute the differences in quality of explanations to the level of cognitive development. In a study of high school chemistry students, Howe and Durr (1982) found students in the late concrete stage of mental operations to be unable to master any aspect of the mole concept, through performance on chemistry test where items generally paralleled the level of cognitive development. Their conclusions included the notion that many concepts in chemistry were beyond the mental abilities of high school students.

Lawson (1982b) reported substantial correlations (r=0.42 to 0.72) among the measures of formal reasoning and achievement in various areas (reading, language, arts, mathematics, social studies and science) using a sample of 72 ninth grade students (mean age 15.1 years). The correlation between formal reasoning and biology achievement came out to be 0.56 for a sample of 72 college students (mean age 23.6 years). When the effect of fluid intelligence was partialled out, the correlation came down to 0.51 which substantiated the existence of strong relation between formal reasoning and achievement. In a study of Saudi Arabian college students, El-Sowygh (1982) through multiple regression analysis noted that among 14 demographic and academic variables formal reasoning was most strongly related to mathematics GPA and amount of course work in science and engineering. Science achievement, cognitive style and IQ were found to be related to cognitive developmental level in a study conducted by Song (1982) on prospective secondary science teachers.

Crenshaw (1983), in a study of non-science majors in a community college, found that formal-operational students significantly outperformed concrete-operational students on biology achievement. McMeen (1983) found significant positive correlations between pre-teach Test of Logical Thinking (TOLT) score and final course grade and between post-teach TOLT and final course grade. In a study of chemistry students in Zambia, Mulopo (1983) investigated the effects of traditional and discovery approaches on learning outcomes for learners of different intellectual growth. The subjects were 120 eleventh grade male students from two boys schools. It was observed that :

(i) for formal reasoners, the discovery group scored significantly higher understanding science scores than did traditional group. For concrete reasoners, the mode of instruction made no difference.

(ii) Overall, formal reasoners earned significantly higher achievement scores than did concrete reasoners.

> Intellectual development seemed to be related to achievement and understanding in science but not to scientific attitudes. Yeany and Porter (1983) in a study of the effects of instructional treatment reported that formal-operational students tended to score significantly higher than less formal students. The effects of cognitive development, age, and inquiry strategies on the achievement of 151 elementary school students in grade one, three and five were studied by Yore (1983). Results from the analysis of achievement data indicated that age became a non-significant factor after grade three, and that cognitive development was a critical factor for both inquiry strategies.

In a study of high school chemistry students, Durr (1984) found that students' cognitive level was significantly and positively correlated with overall (unit) test scores and with percent success on test items. The purpose of a study by Gabel, Sherwood and Enochs (1984) was to determine the general problem-solving skills that students use in solving problems involving moles, stoichiometry, the gas laws and molarity. The strategies were examined for success in problem-solving for 266 students of varying proportional reasoning ability. Results indicated that successful students and those with high proportional reasoning ability tended to use algorithmic reasoning strategies more frequently than did unsuccessful and low proportional reasoning ability students. However, the majority of students solved the chemistry problems using only algorithmic methods, and did not understand the chemical concepts on which the problem was based.

Little (1984) conducted a study to look into the instructional effectiveness of a programming technique on the achievement in BASIC language and logical thinking measures of secondary school students and reported that formal-operational students scored higher than concrete/transitional students on both the programming and logical thinking measures.

McKenzie (1984) assessed the effects of three instructional strategies on the graphing achievement of 101 eighth grade students. On the basis of results, he concluded that transitional/formal-operational tended to score higher than concrete-operational students on the graphing achievement measure and the effects of treatment on achievement across levels of cognitive development appeared to have been consistent.

The efficacy of game advance organizer on improving the achievement of formal and concrete learners (n=109), in tenth grade biology classes studying the Mendelian genetic principles of segregation and independent assortments, was investigated by Milka (1984). The author reported that concrete learners, regardless of treatment, scored significantly lower on a genetic problem-solving test than formal learners. Peabody (1984) found that both transitional and formal thinkers in the experimental group (which used specific concrete examples, analogies, and the physical manipulation of stick and ball models) significantly outperformed their counterparts in the control group in achievement. Formal thinkers performed significantly better than transitional thinkers within the experimental group. Work (1984) conducted a study on seventh grade life science students (n=122) from a sub-urban junior high school and reported that developmental level and problem-solving ability were significantly related. He further added that the best problem solvers were field-independent and formal-operational or transitional.

Hofstein and Mandler (1985) studied Israeli high school students and reported that formal thinkers scored significantly higher than nonformal thinkers in mathematics, physics, chemistry and biology. This result was supported by the findings of Abraham and Renner (1986) who found that formal students scored higher on concept achievement tests in chemistry. A high positive correlation ($r=0.60$, $p<0.001$) was reported by Tobin (1986) between formal reasoning ability and science achievement.

Farrell and Farmer (1985) conducted a study on college-bound adolescents and found that prior experience in mathe-

matics and science were significantly related to first-order direct proportional reasoning. However, they did not find significant relationship between either of these two variables with multiple proportional reasoning. The role of developmental level in undergraduate science course students' (n=25) ability to balance chemical equations was investigated by Niaz and Lawson (1985). Investigators reported significant correlations between developmental level and equation balancing ability for both simple and complex equations.

Some studies reported low to moderate correlations between operational reasoning/cognitive developmental level and science achievement. Wheeler and Kass (1977) attempted to relate subjects' proportional reasoning ability to achievement in introductory chemistry, using 168 grade ten chemistry students. The highest correlations with chemistry achievement was demonstrated by chemistry proportionality subtests. Piagetian reasoning test and the general proportionality test showed moderate correlation (0.48 and 0.41) but did not add significantly to a regression equation predicting chemistry achievement from the chemistry proportionality subtests.

Griffiths and Kass (1979), using a sample of 269 grade ten chemistry students, found low correlations (0.09 to 0.36) between scores on groups of hierarchically arranged chemistry skills and scores on a neo-Piagetian test. Here also, the developmental level scores did not add significantly to the prediction of subsequent chemistry scores by scores on test of prerequisite chemistry skills. Wilson and Wilson (1984 a, 1984 b), in a study of all students begining either the two-year National High School or the one-year Preliminary Year Programme in Papua, New Guinea, in 1980, reported low correlations between cognitive level and science grades.

Some studies did not even find significant relationship between cognitive development and achievement. Kishta (1979), in his study of fourth, fifth and sixth graders, did not find evidence of a relationship between level of cognitive deve-

lopment and achievement as measured by a standardized achievement test (Iowa Test of Basic Skills). Collins (1979) studied 100 tenth and twelfth graders and found no evidence of a relationship between their cognitive development and achievement in physics. Students of different cognitive development were found to achieve similarly on a criterion test of problem-solving in a study conducted by Grant (1979). Stopler (1979) did not find evidence to support a relationship between level of cognitive development and achievement in Intermediate Science Curriculum Study.

In addition to these studies, some more studies found cognitive development level not useful for predicting achievement. No significant relationship between cognitive development and achievement in classical mechanics was found by Champagne et al (1979), Charoenpit (1979) with 176 students in chemistry, Cole (1979) in a general science achievement test, Dallan (1979) for 303 students in natural sciences course, Filson (1979) with 170 students in Geology, Hill (1979) with 88 students in a problem-solving achievement test and Williams et al. (1979) with 861 science majors and nonscience majors in chemistry did not report any significant relationship of achievement with cognitive development.

Hartford (1980) found that Piagetian level of intellectual development did not differentially affect the questioning skills of first year high school chemistry students in the context of laboratory experiments. Hofstein and Mandler (1985) did not obtain significant differences in achievement of concrete and transitional students. One possible reason for these contradicting results of the influence of a student's level of cognitive development on science achievement may rest in the closeness between the level of reasoning required for successful performance on the achievement measures. As illustrated by Walker et al. (1979), the cognitive demand of the criterion measures may be more readily visualized in a specific test than in a general criterion measure of total course grade.

Some researches tried to predict achievement through

cognitive developmental level and some other relevant variables. Raven and Polanski (1974), in an attempt to predict content comprehension, reported that seven subtests of RTLO (Raven's Test of Logical Operations) predicted the greatest amount of variance for the Science Content Comprehension Test (40%) and the Iowa Comprehension Test (39%). The RTLO was also used in a study reported by Raven et al. (1974), who found that seven subtests of RTLO predicted the greatest amount of variance for the Test of Seience knowledge (37.6%) with nearly one-fourth of the variance in the Iowa Silent Reading Test. In a study of ISCS classes, Howe and Early (1979) provided evidence that logical thinking accounted for 26% of the variance in science achievement. Inclusion of informal reading test and reading abilities of students adds another 6% of the variance to be accounted for.

Lehman (1980) studied the effectiveness of Piagetian-based and inquiry-oriented strategy for teaching high school biology and found that IQ was the best predictor of achievement for city youth and the Piagetian pretest for the rural youth. Using stepwise regression analysis, Pallrand and Moretti (1980) tried to establish the relationship between aptitude scores, number of years of course work in school subjects, and Piagetian classification as derived from clinical interviews for solutions, balance, and coloured token tasks. Aptitude scores and IQ correlated moderately ($r=0.40$ to $0\ 60$) with Piagetian classification as did science credits ($r=0.41$) and mathematics credits ($r=0.39$), Multiple regression analysis showed that aptitude variables contributed 44% of the variance on the balance test, and 9% and 10% respectively on the solutions and colour token tasks. Sherwood (1980) hypothesized and found through multiple regression analysis, that students scoring high on an aptitude test for proportional reasoning were also better problem solvers of mole concept and stoichiometry problems in chemistry. Controlling variables and Islands Puzzle tasks were shown to account for 45.7% of the variance in BSCS Achievement Test I results, in a study conducted by Glass (1981).

Helseth et al. (1981) reported that Scholastic Aptitude Test (SAT), followed by level of cognitive development were the best predictors in college biology. 500 physics students were tested on a battery of pretests, including mathematics, SAT, spatial rotation, deductive reasoning, inductive reasoning and spatial visualization by VanHarlingen (1981). Factor analysis indicated that logical/verbal, spatial, and mathematical ability explained 31% of the achievement variance. Chiappetta and Russell (1982) studied 140 students enrolled in earth science course. Using multiple regression analysis, they provided evidence that level of cognitive development accounted for 15% ($p < 0.001$) and 17% ($p < 0.001$) of the variation in knowledge level and application level achievement, respectively. Further, they showed that cognitive developmental level accounted for more of the variance in tests of achievement than did modification of instructional treatment. Jain (1982) hypothesized that IQ, creativity and level of intellectual development influenced the problem-solving ability in physics (before and after providing hints) in the same way. His findings indicated that level of intellectual development and IQ accounted for the significant amount of variance in problem-solving before providing hint while only intellectual development accounted for significant amount of variance in problem-solving after providing hint.

Dettloff (1983) designed a study to formulate a predictive equation to identify community college biology students ($n=420$) who most probably would not succeed in a science course. Background characterists and reading mathematics ability accounted for 42% of the variance in achievement. Cognitive development accounted for 12.8% of the variance in achievement. Lawson (1983) conducted a study on undergraduate students enrolled in three sections of a biological science course for elementary teachers and reported that developmental level was found to be the best predictor of performance on the multiple choice items. Lawson found that developmental level accounted for 28% of the variance for prediction of performance on Geologic Time Items.

Staver and Halsted (1984), in a study of 105 high school students enrolled in chemistry, reported on the basis of regression analysis that scores on Piagetian Logical Operations Test (PLOT) significantly predicted achievement. Hofstein and Mandler (1985), in order to obtain more insight into the issue of the discriminating ability of Lawson's Test, conducted a stepwise regression analysis in which the various subscales of Lawson's Test served as independent variable while achievement in science (biology, chemistry and physics) and mathematics served as dependent variables. The investigators found that in case of mathematics, physics and chemistry, only probabilistic reasoning explained significant amount of variance in achievement. As regard to biology, however, they reported that items that measure probabilistic reasoning, conservation of weight, displaced volume, combinatorial reasoning, and proportional reasoning explained about 30% of the total variance of students' achievement. Staver and Halsted (1985), working with high school chemistry students, reported that Piagetian reasoning accounted for a significant portion of the variance in the total score, memory score. and application score, but not on the synthesis score of the achievement test. Tobin (1986) found that variation in formal reasoning accounted for approximately 36% of the variance in science achievement.

2.4 Studies Related to Interaction Effect of Cognitive Development and Other Variables on Science Achievement

The researcher could not trace out a single study related to interaction effect of cognitive developmental level and achievement motive on science achievement. However, some studies related to interaction of cognitive development and some other variables are available. Peters (1980) investigated the interaction relationship between cognitive development and patterns of achievent for four modes of secondary instruction in science. Inquiry process skills and general scholastic achievement in six ninth grade classes (n=161) were the criterion variables. Significant interactions were found for

similar modes Significant three-way-mode × cognitive level × gender — interaction were found for differences in scholastic achievement.

Interaction between logical thinking and instructional treatment was not found to explain significant amount of variance in achievement of the earth science subject matter in study conducted by Chiappetta and Russell (1982) on 170 eighth grade students entrolled in earth science classes. Crenshaw (1983) conducted a study to determine the effects of a reinforced teaching and lecture—only teaching methods in biology on achievement of non-science majors in a community college and examined the interaction effect between the two teaching methods and the students' level of cognive development. He found that there was no significant interaction between the level of students' cognitive development and teaching method.

Staver and Halsted (1985), working with high school chemistry students, reported that three-way interaction of Piagetian reasoning, model usage, and sex type accounted for a significant portion of the variance in total scores, and in the memory and application sections of the achivement test. Abraham and Renner (1986) reported the presence of interaction effect between class level and developmental level on the concept achivement test in chemistry.

2.5 Studies on Relationship of IQ and Piagetian Tasks

Studies related to IQ and Piagetian tasks did not level consistent results. Findings showed varying results from low to very high relationships. Piagetian tasks and IQ relationships have been reported to be low by Beard (1960) and Dodwell (1960, 1962), Kohlberg and DeVries (1974) in a factor analytic study demonstrated that Piagetian measures defined factors separate from psychometric intelligence factors. In their study involving bright and average six-year-olds, Kohlberg and DeVries found three factors :

(a) General psychometric intelligence (subject built from varied psychometric measures);

(b) Conservation (liquid, length, ring segment);

(c) Classification (Sorting and class-inclusion). Webb (1974) observed that, "Perhaps that most comprehensive position is that of Kohlberg and DeVries (1974) who argue that the traditional IQ test has been refined to miximize the contribution of an hereditary component of intelligence roughly equivalent to Spearman's "g", while Piagetian tasks reflect more of the experimental side of an interactive process of intellectual growth and, therefore, might be more relevant to educational assessment", Hathaway and Hathaway—Theunissen (1974) argued that in Piagetian psychometry the tasks are structured and interpreted according to a logic rather than a mere statistical comparison with other children. Valentine (1975) reported that high convergent thinking did not guarantee success on reasoning tasks.

Moderate relations between IQ and Piagetian tasks have been reported by Elkind (1961), Almy et al. (1966, 1967) and Dudek et al. (1969). Correlations between mental age and Piagetian performance at a moderate level have been reported by Mannix (1960), Kohlberg (963) and Freyberg (1966). The data gathered by Dudek et al., on 100 children aged from five through eight years of age, was analysed by Hathaway (1973). Three independent factors were computed :

(a) WISC subtests;

(b) Seven Piagetian tasks;

(c) California Achievement Test subtests, a few WISC subtests, and four Piagetian tasks. Overall, some degree of overlap and some degree of non-overlap of psychometric and Piagetian measures of intelligence is demonstrated by this study.

Children with "superior" intelligence were reported to have shown more mature response patterns on Piagetian-type tasks than children of the same age with "average" intelligence test scores in a study by Little (1972). Cloutier and Goldschmid (1976) found significant correlations between scores on proportion test and non-verbal intellectual capacity as measured by Raven's Progressive Matrices. Issacon (1977) showed that Piagetian tasks correlated significantly and positively with WISC test and the performance on psychothematic intelligence was more positively correlated with the Piagetian tasks scores than with the chronological age. The author suggested that the developmental tests might provide a viable alternative to IQ tests as culture-free indicators of cognitive level and learning ability for young children, and enhance educational planning when used in conjunction with psychometric data. Sandhu (1980) and Raizada (1982) reported that measures of intelligence correlated significantly with Piagetian tasks in the positive direction. The notion of the impact that intellectual development has on students' abilities was reinforced by Marek (1981), who found strong relationships between Piagetian stage and IQ, content achievement, and inquiry skills in ninth and tenth graders and by Lazarowitch (1981), who found significant correlations between classification ability and intelligence. Alport (1983), using a sample of 100 high school and college students showed that there was a significant relationship between Piagetian tasks and IQ, with performance improving with increasing IQ. In a study of seventh grade life science students from a sub-urban junior high school, Work (1984) reported a significant and positive relationship between IQ and cognitive developmental level.

Niaz and Lawson (1985) reported extremely high correlation between developmental level and performance on the Raven's Test ($r=0.69$). After correction for attenuation the co-efficient was nearly 1.0 (0.97). This high correlation supported the position of Lawson (1979), who viewed the Raven Test, at least in part, as a measure of developmental level because that seemed to require the use of strategies normally associated with Piaget's stage of concrete and formal reasoning.

However, leaving one or two researches, no researcher paralleled the measures of cognitive development at par with general mental ability tests evolving from psychometric measures. Lawson's (1979) study, also, supported replacing Raven's Progressive Matrices in part to measure Piaget's stages due to requirement of the use of strategies. Most of the other studies, though found IQ to be positively and significantly related with cognitive development level, considered it to be a separate variable than just the same as intelligence tests in general.

Review of researches in different sections of this chapter point towards the need of a fresh research with objectives already mentioned in chapter 1.

3

Design and Procedure : Part 'A' Development and Description of Tools

This chapter concentrates upon the selection and development of tools for the present study, Selection of tools by the researcher depended upon various considerations, such as, the objectives of the study, the span of time at the disposal of the researcher, availability of appropriate tests, personal competence of the investigator to administer, score and interpret the results, etc. To have interpretability of data, tools must possess a satisfying level of the following characteristics :

(a) reliability,
(b) validity,
(c) sensitivity,
(d) appropriateness,
(e) objectivity,
(f) feasibility, and
(g) ethical standards (Fox, 1969).

With these considerations in view, the following four tools were used for the present study :

1. Tarkik Chintan Parikshan (F.O.L.P., F.O.P., F.C.O.)
2. Concept Attainment Test in Physics (Force, Couple, TIR and Atom)

3. Test of General Mental Ability

4. Achievement Motive Inventory

Search for a group test of logical thinking ended with the adaptation of a French test (Longeot, 1962, 1965), in Hindi, to suit the purposes of the present investigation. Concept attainment tests in Hindi on Couple and Total Internal Reflection (Bhattacharya and Pandey, 1981) and on Force and Atom (Bhattacharya and Pandey, 1985) were used to suit the level of students in the sample. Relevant details about the tools used in the study, adapted or considered as standardized, are given in the following sections.

3.1 **Tarkik Chintan Parikshan**

For the purpose of measuring operational reasoning and classifying students into concrete—and formal-operational stages, Hindi adaptation of the Longeot Test (1962, 1965), a paper-pencil measure of cognitive development, was made.

Rational for the Use of Group Test : With increased interest in the application of Piagetian theory by the teachers in the field of science education there has developed a need for an instrument to assess effectively the cognitive levels of large number of students at a time. Such instrument can be used to determine the proportion of concrete and formal-operational students which may further facilitate to design classroom activities more tuned to the capabilities of the students. Individually administered Piagetian tasks are widely accepted as valid method for making these determinations (Goldschmid, 1967 ; Lovell and Shields, 1967; Goldschmid and Bentler, 1968; Bart, 1971 ; DeVries, 1974 ; Lawson, Blake and Nordland, 1974 ; Lawson, Nordland and Kahle, 1975 ; Lawson and Renner, 1975 ; Lawson and Blake, 1976, but they suffer from the weakness of being time-consuming and, therefore, restrictive for classroom use. Additionaly they require trained interviewers and inter-rater reliability checks to ensure consistent scoring, For

these reasons, many researchers have tried to develop and evaluate more objective instruments to measure this aspects of development, such as reasoning which may be valid, reliable, simple to administer and score, and less time and money consuming.

On the basis of test administration formats, the group tests of logical thinking may be classified into two main categories (i) pure paper-pencil measures (Longeot, 1962, 1965 ; Tisher, 1971 ; Bart, 1972 ; Raven, 1973 ; Tisher and Dale, 1975 ; Milakofsky and Patterson, 1975 ; Sills, 1977 ; Sandhu, 1980 ; Tobin and Capie, 1981) and (ii hybrid measures, a compromise between strictly paper-pencil tests and clinical interviews. This category consists of tests containing Piagetian type tasks presented simultaneously to the whole group (Raven, 1973 : Shayer and Wharry, 1974 ; Rowell and Hoffman, 1975 ; Lawson, 1978). Review of literature reveals that the controversy of group test vs. clinical interviews is not yet resolved.

Many studies (Keating and Clark, 1980 : Tschopp and Kurdek, 1981 ; Farmer et al., 1982 ; Stefanich et al., 1983) reveal that group administered tests are not as valid as individually administered Piagetian tasks. Paper pencil type of Piagetian tests were compared with individually administered Piagetian tasks using a sample of high school students by Tschopp and Kurdek (1981) and university students by Stefanich et al. (1983). The investigators reported that the correlations were not sufficiently strong enough to warrant selection or categorization of individual student on their paper-pencil test performance. Keating and Clark (1980) reported that written Piagetian tests deviate significantly from clinical interviews and may not provide an appropriate test for determining cognitive abilities. Farmer et al. (1982) attempted to determine the degree of congruity among estimates of cognitive development based on three different measures, two paper-pencil tests and one interview protocol. Authors found that paper-pencil instruments provided a less rigorous definition of formal operations than do interview techniques. Brown (1974) and Roberts (1980) questioned the advisability of using paper-pencil tests as a substitute for clinical interviews in ascertain-

ning an unbiased estimate of formal operations ability. According to them, studies conducted using clinical interviews and paper-pencil tests could not be compared as the interpretations of scores are not the same and the letters have limited generalizability.

However, there are many studies which support the use of group administered tests. Rowell and Hoffman (1975) in a study of high school students reported that it was possible to translate into group form, administer, and assess rapidly and with considerable realiability Piagetian type problems as indicators of developmental level. They, however, reported that the group method of administration lost some of the sensitivity inherent in the clinical approach as employed by skillful workers. But, it had the marked advantages that it could be utilized by teachers who, usually, had no such training, and could be used with whole class at a time. Renner et al. (1978) reported that written and individual interview results agreed in 94% of the cases. Walker et al. (1979) indicated that the translation of conventional Piagetian formal tasks into a reliable written form was feasible. Staver and Gabel (1979) designed the Piagetian Logical Operations Test (PLOT) as a multiple-choice, group-administered test to function as an alternative to clinical interviews. They establish both convergence and discriminance validity and reported reliability estimate of 0.85 based on internal consistency. A group test intended to measure formal-operational reasoning was developed by Maggio (1982) who modified the Lawson's test (1978) to include test items measuring correlational reasoning. A variety of procedures was used to demonstrate the reliability (r=0.78) and validity of the instrument. Maggio (1982) concluded that the modified classroom test is a reliable and valid measure of formal operations. Roadrangka et al. (1983) developed the Group Assessment of Logical Thinking (GALT) and conducted clinical interviews as a means of investigating the validity of GALT. The authors concluded that GALT validity measured the logical operations and could reliably be administered in one class period.

Birdd (1982), working with grade nine students, obtained comparable results from a group test and a process of questioning during class demonstration. Pearson (1982), employing 192 secondary students, found no significant difference between group testing and individual interviews. Lawson's (1978) observation that use of physical materials provides an important motivation and sense of meaningfulness has not been supported by Carlson and Streitberger (1983). Staver (1984) in a study of the effect of method and format on subjects' performance noted that the case for assessment of Piagetian reasoning patterns by group methods was strengthened as method of assessment did not account for significant amount of variance in students' performance.

Some studies were conducted to investigate the effect of format, mode of presentation and content on the responses of the subjects. Findings, however, were not unanimous.

Lawson and Blake (1976a) found that Piagetian tasks were relatively content free and, thus, were realistic indicators of concrete and formal thinking abilities. Reif (1984) used 18 item paper-pencil test to assess the ability to separate and control variables and proportional reasoning of freshmen university students and reported that tests used to assess reasoning abilities appeared to be unbiased by content. However, Linn et al. (1981) and Linn et al. (1983) reported that content and problem effects contributed to significant variance on formal reasoning problems.

Staver and Pascarella (1984) investigated the effects of various methods and formats of administering Piagetian task problems on a sample of college biology student and reported that neither method nor format accounted for significant amount of variance in student performance. In addition, they reported that the overall interaction remained non-significant. In other study, Staver (1986) investigated the effect of problem format on the responses of students to a control of variables reasoning task using a task of great difficulty (Bending rods

problem) and found that task format had no effect on subjects' scores. Whereas, in an earlier study, Staver (1984) and uncovered a significant format influence on another control of variables reasoning problem (Mealworm task), However, method of assessment was not found to account for significant amount of variance in subjects' scores.

3.1.1. Rationale for the Selection of Longeot Test

Instead of going all out for constructing a new battery of tests, it was economical and time saving for the researcher to adapt some suitable test for the intended population, keeping, of course, in view other factors which may affect the realization of objectives.

Longeot (1962, 1965) was, perhaps, the first to develop a paper-pencil group test of logical thinking on Piagetian lines (Ahlawat and Billeh, 1982). Since then, several researchers, as noted in section 3.1, attempted to construct group measures of logical thinking. Although their efforts were commendable, as aptly noted by Staver and Gabel (1979), each one of them fell short of one or more of the essential prerequisites of effective measuring instruments. Farmer et al. (1982), critics of group assessment, had noted that further revisions and subsequent analysis to improve the correspondence of test item difficulty with the genetic structure of Piaget's stages made Longot's validation efforts far superior to those of many others. Nagy and Griffiths (1982), in their review, analyzed the results of nine attempts to develop group test and presented them in a rough order of ascending quality. Out of these nine tests, Longeot's test was judged to be the best. The present investigator selected this particular instrument keeping in view the above comments along with various points as given below :

(a) Longeot's test was developed keeping in view the real spirit of Piagetian concept of developmental stages of logical thinking (Gray, 1970; Ahlawat and Billeh, 1982).

(b) It stood the test of time and proved useful in variety of research studies in several countries (Sheehan, 1970; Cummins, 1977; Lawson and Blake, 1976; Days. 1977: Bachuroff, 1980; Blake, 1980; Gabel and Sherwood, 1980; Johnson, 1980; Peters, 1980; Pluta, 1980; Ward and Herron, 1980; Ward et al., 1981: Pilacik, 1983).

(c) It employed several items to measure each one of four operational resonings so as to provide a reliable assessment of each reasoning.

(d) It is easy to administer and does not require more than two normal instructional period of time,

3.1.2. Description of the Longeot Test

The Longeot test (1962, 1965), in French, is a twentyeight item paper–pencil test designed to measure various aspect of operational thought. It contains four distinct part. Part I consists of five items involving the concept of class—inclusion which apply to concrete operations (seriation of relations, transitive composition of classes and relations, reversibility of relations). Part II of the test contains six propositional logic items which call for formal operations (negation or inversion of disjunction and implication, distinction between implication and equivalence). Part III of the test has nine proportion reasoning items of which five call for concrete operations and four formal operations. Part IV consists of eight combinatorial reasoning problems which require the subject to list all possible combinations of a set of items. Out of these eight problems, four require concrete-operational reasoning and the remaining problems require formal-operational reasoning.

As regards the reliability of the Longeot test, Lawson and Blake (1976b) reported a KR-20 coefficient of 0.85 and Ward et al. (1981) reported it from 0.72 to 0.78 over a wide range of class types. Sheehan (1970) reported it to be 0.87. Blake (1980), using a pilot group of grade 10-12 students, reported a test-retest reliability coefficient of 0.80.

The validity of the Longeot Test was established by Longeot (1965) by applying the Guttman's hierarchical analysis. This analysis verified the conformity of test items with Piaget's theory of cognitive development relative to the concrete-operational and formal-operational stages. Lawson and Blake (1976 b), using a nineteen-item abridged from the English version of the Longeot test, reported a significant Chi-square ($\chi^2=17.9$, $p<0.02$), an evidence of concurrent valiuity of the Longeot test with performance on four Piagetian tasks. Ward et al. (1981) reported a significant correlation ($r=0.62$, $p<0.01$) between scores on the Longeot test and the sum of scores on two Piagetian tasks (balance beam, flexible rods).

As mentioned earlier some of the items of the Langeot's test require concrete-operational reasoning while others require formal-operational reasoning. Table 3.1 provides original classification of Longeot's test items.

Table 3.1

Original classification of Longeot's test items

Classification	Test items
Concrete	1, 2, 3, 4, 5, 12, 13, 14, 14, 15, 21, 22, 23
Formal	6, 7, 8, 9, 10, 11, 16, 17, 18, 19, 20, 24, 25, 26, 27, 28

Ward et al. (1981) provided the evidence on the basis of factor analysis of the test items that their classification as concrete or formal was not directly related to item difficulty. Items 17 and 24, which had originally been classified as formal, loaded predominantly on the concrete factor. Question 17 appeared, by inspection, to be similar to questions 12-15 in its method of solution. Item 24 can be solved by employing a simple algorithm or merely by adding the extra information to

problem 23. For this reason, Ward et al. (1981) placed questions 17 and 24 with other concrete questions, Table 3.2 provides the revised classification of Longeot's test items.

Table 3.2

Revised classification of the Longeot's test items Ward et al. (1981)

Classification	Test items
Concrete	1, 2, 3, 4, 5, 12, 13, 14, 15, 17, 21, 22, 23, 24
Formal	6, 7, 8, 9, 10, 11, 16, 18, 19, 20, 25, 26, 27, 28

Ward et al. (1981) reported that the revised classification scheme, when compared to the original classification, resulted in the increase of correlation from 0.49 to 4.62 between classification based on the Longeot's test and Piagetian tasks (balance beam, flexible rods).

3.1.3 Adaptation of Longeot's Test in Hindi

Originally, the Longeot test was constructed in French language. In U.S.A., Sheehan (1970) adapted the test into English. The present investigator had both versions of the test—the origional, in French, and the English version by Sheehan. The original test was first translated into English and then this translation was matched with Sheehan's translation. No difference was found between this translation and Sheehan's adaption except in case of certain words which might have been culturally oriented to French students. Then it was translated into Hindi language. Specific words, which were found to be culturally oriented to French students were changed to make it suitable to Indian conditions. No words were changed which had a direct bearing on the structure of

the question. For example, English translation of question no. 21 from the original test reads as :

> After the dinner of the family, it was decided to dance.
>
> There are three men :
> ALBERT, BERTRAND, CHARLES
> and three women :
> LOUISE, MONIQUE, NICOLE
>
> What are all the possible pairs (mens with women) of dancers in this free/extempore dance ?

Since, a practice of dance after family dinner is very much uncommon in India, particularly in an area where this study was to be conducted, a free/extempore dance as asked in the question is something unthinkable. Modification having no bearing on the structure of the question, was made as follows :

> In a dance ceremony, three male and three female dancers are participating.
>
> Male dancers are :
>
> DHIRENDRA, SATYENDRA, RAJENDRA
>
> and female dancers are :
>
> NIHARIKA, ANAMIKA, LATIKA
>
> What are all possible pairs of dancers—
> male dancer with female dancer ?

After such translations with unavoidable changes wherever required, language experts were consulted regarding the accuracy of translation, functional usage of words, etc. and necessary corrections were made in the light of their suggestions. Since formal thinking begins at the age of approximately 11^+, so while translating and rewriting the items, the researcher was conscious that students of seventh-eighth grades should not fail to answer an item just because of their inability

to read them. Teachers teaching in junior high school and high school were requested to look at the items from the viewpoint of readability of seventh-eighth graders. Items were rewritten incorporating their suggestions. Finally, a random sample of 60 students, 23 each from VII, VIII and IX grades was chosen and the test was administered to them. The sole purpose of this testing was to determine meaningfulness of vocabulary. Reaction of respondents were noted and modifications were made accordingly. The final form of the test is given in Appendix I.

Next step was to determine timing for completion of the test. This test requires that respondents be given sufficient time and be allowed to pace themselves to respond. Time was bound to vary from one grade to another. After administering the test to various grades, the following schedule was found suitable for grades IX to XII and timing announcements were made accordingly.

Part I : 5 minutes
Part II : 15 minutes
Part III : 25 minutes
Part IV : 30 minutes

3.1.3.1 **Psychometric Details of the Test**

In order to have informations about item statistics and other psychometric details about the test, it was administered to a sample of 884 science students, from grades IX to XII, selected from various schools of Varanasi city. Grade and sex-wise description of the sample has been presented in Table 3.3. Mean and s.d. of age of different grade students are shown in Table 3.4.

Difficulty value and discriminating index for each item were computed. No item was discarded on the basis of item difficulty (the purpose being to find out the possession or absence of reasoning ability). The sole purpose of their computation was to get information about the fraction of

Table 3.3

Sample in relation to sex and grade

	IX	X	XI	XII	Total
Boys	66	44	228	112	450
Girls	64	135	140	95	434
Total	130	179	368	207	884

Table 3.4

Mean and standard deviation of age (in years)

	IX	X	XI	XII
Mean	13.97	15.26	16.12	17.08
S.D.	0.73	0.64	0.78	0.66

students giving the required response for a particular item. The item statistics were compared with those of Ward et al. (1981) and Ahlawat and Billeh (1982) for their sample from U.S.A. and Jordan, respectively. Ward et al. (1981) obtained data from college chemistry students in the age-range 17-20 years while Ahlawat and Billeh (1982) obtained it from XI-grade science students of the age-group 15-20 years with the mean age of approximately 17 years. Item statistics for the present sample with those of Ward et al. (1981) and Ahlawat and Billeh (1982) have been presented in Table 3.5.

Table 3.5 reveals that difficulty values for concrete items range from 0.38-0.89 for IX graders, from 0.29—0.93 for X graders, from 0.51-0.93 for XI graders and from 0.53-0.98 for XII graders. For formal items, they range from 0.02-0.64 for IX graders, from 0.04-0.73 for X graders, from 0.06-0.69 for XI graders and from 0.07-0.70 for XII graders. Item parameters of Longeot's test indicate that for grades IX to XII, item nos. 1-5 are very easy and item nos. 8, 10, 27 and 28

Table 3.5

Item statistics for Longeot's Test items

Item No.	Grade IX		Grade X		Grade XI		Grade XII		Data from Ward et al. (1981)	Data from Ahlawat & Billeh (1982)	
	D.V.	D.P.	D.V.	D.P.	D.V.	D.P.	D.V.	D.P.	D.V.	D.P.	D.V.
1	2	3	4	5	6	7	8	9	10	11	12
1	.89	.12	.93	.10	.93	.11	.98	.08	.96	.10	.90
2	.87	.25	.72	.56	.84	.30	.87	.23	.88	.29	.85
3	.84	.31	.73	.53	.85	.26	.85	.27	.95	.20	.90
4	.86	.16	.79	.42	.91	.23	.92	.17	.95	.28	.90
5	.73	.47	.71	.53	.81	.32	.87	.27	.92	.08	.89
6	.34	.50	.53	.67	.51	.64	.53	.44	.64	.30	.53
7	.47	.69	.34	.38	.42	.61	.47	.40	.56	.42	.38
8	.02	.08	.04	.08	.06	.13	.07	.18	.09	.21	.08
9	.48	.78	.53	.62	.59	.71	.64	.61	.69	.45	.59
10	.04	.08	.10	.16	.19	.21	.23	.35	.53	.38	.22
11	.31	.50	.43	.78	.51	.48	.59	.59	.47	.37	.27
12	.63	.38	.61	.33	.72	.43	.75	.34	.91	.36	.63

Contd. **Table** 3.5

1	2	3	4	5	6	7	8	9	10	11	12
13	.64	.28	.69	.22	.80	.39	.84	.33	.95	.32	.76
14	.67	.53	.73	.23	.77	.44	.80	.36	.85	.41	.77
15	.77	.34	.72	.33	.81	.38	.83	.31	.93	.34	.78
16	.19	.25	.37	.56	.46	.71	.52	.58	.78	.42	.38
17	.55	.41	.52	.56	.51	.40	.53	.44	.70	.38	.61
18	.30	.47	.48	.60	.53	.63	.59	.75	.71	.45	.59
19	.33	.59	.46	.73	.59	.76	.59	.75	.79	.47	.59
20	.64	.53	.73	.49	.69	.49	.70	.60	.79	.39	.69
21	.48	.59	.60	.76	.73	.50	.71	.54	.95	.33	.80
22	.38	.56	.58	.58	.68	.69	.67	.54	.97	.40	.69
23	.41	.56	.46	.73	.60	.70	.64	.65	.94	.34	.71
24	.38	.56	.29	.49	.54	.67	.53	.60	.74	.39	.54
25	.45	.84	.46	.78	.57	.82	.58	.77	.81	.36	.64
26	.05	.09	.11	.22	.35	.74	.41	.65	.58	.34	.26
27	.05	.16	.10	.23	.16	.29	.17	.33	.43	.51	.23
28	.08	.16	.12	.31	.20	.42	.20	.40	.50	.48	.24

seem to be very difficult. Item no. 26 is very difficult for IX and X graders only. Though, being not a comparative study at the cross cultural level, item parameters for IX-XII graders obtained from Varanasi sample are very much similar to those obtained from U.S.A. sample by ward et al. (1981) and Jordanian sample by Ahlawat and Billeh (1982). While the present item difficulty and those obtained from Jordanian sample are remarkably similar, a slight difference exits between Varanasi sample and U.S.A. sample as regards to item nos. 8, 10, 27 and 28. However, Table 3.5 clearly reveals the culture fairness of the Longeot's test and cross-cultural generalizability of its item parameters and thereby increases researcher's confidence in the soundness of the test.

The results, to become consistent with the ontogenetic aspect of Piaget's theory of cognitive development, should show that with increase in age there is :

(a) an increase in the percentage of students in the formal operational stage, and

(b) a decrease in the percentage of students in the concrete-operational stage. To verify this aspect, students were categorized as belonging to early concrete-operational (II-A), and late concrete-operational (II-B), early formal-operational (III-A) and late formal operational (III-B) level on the basis of their total score on Longeot's test and the schedule laid down by Ward et al. (1981). Table 3.6 shows categorization of students into different operational levels across various grades.

It is clear from Table 3.6 that percentage of students at concrete-operational stage is decreasing and at formal-operational stage is increasing with the increase in age and grade. This result is consistent with the ontogenetic aspect of Piaget's theory of cognitive development.

Reliability : According to National Committee on Test Standards (1967), if test score is a measure of a generalized,

Table 3.6

Percentage of students at different cognitive developmental levels

Levels	Grades							
	IX		X		XI		XII	
	n	%	n	%	n	%	n	%
II-A	9	6.92	12	6.70	19	5.16	2	0.97
II-B	100	76.92	106	59.22	213	57.88	99	47.82
III A	18	13.85	52	29.05	91	24.73	61	29.47
III-B	3	2.31	9	5.03	45	12.23	45	21.74
Total	130	100.00	179	100.00	368	100.00	207	100.00

homogeneous trait, evidence of internal consistency should be reported and whenever reliability coefficients based upon internal analysis are reported, speed of producing response should have a negligible influence on scores. Since the items of this test are sampled from a relatively homogeneous universe and speed has no influence on its scores, a measure of internal consistency was sought to be computed. For this, a sub-sample of 100 students was drawn randomly from the sample of XI grade science students and KR-20 coefficient of reliability was computed. It was found to be 0.78. This shows that the instrument is reliable as its internal consistency coefficient is high Test-retest reliability was also computed. For this, the test was readministered to a group of 87, XI-grade students, selected from one boys' and girls' intermediate college, two weeks after the first administration of the test. The test-retest reliability was found to be 0.81.

Validity : Gray (1970) stated that questions of validation of group tests should include the extent to which (i) paper-pencil items are based on actual Piagetian tasks, and (ii) performance on a battery of items exhibits the hierarchical performance expected by Piagetian theorists.

To answer the first question, an inspection of items of this test was made which revealed that items were based on Piagetian tasks as found by earlier investigators also (viz., Gray, 1970 ; Sheehan, 1970 ; Ahlawat and Billeh, 1982). As regards to the second question, Longeot (1965) verified the conformity of the test items with Piaget's theory of cognitive development relative to the concrete-operational and formal-operational stages by applying the Guttman's hierarchical analysis. As already mentioned in section 3.1.2, Lawson and Blake (1976b) and Ward et al. (1981) reported it to be a valid instrument by correlating scores on Piagetian tasks and the Longeot test.

For the present investigation, the concurrent validity of the test was determined by computing the correlation among scores on this test and those of Sandhu's (1980) 'Kishoron Ki Vichar Prakriya' and Tobin and Capie's (1981) 'Test of Logical Thinking'. These three tests were administered to a sample of 100, XI-grade science students. Correlation of the present test with Sandhu's test was found to be 0.61 and with that of Tobin and Capie's test was found to be 0.69. These correlation co-efficients show that Longeot's test of cognitive development is a valid instrument. Since, Tobin and Capie's test employs items of only formal-operational reasoning, hence one more correlation was computed between scores on Tobin and Capie's test and total of scores on formal items of the Longeot's test. The value of this correlation coefficient came out to be 0.76. This also shows the validity of formal operations items of the Longeot's test. Data in Table 3.6 confirm that they are consistent with the ontogenetic aspect of Piaget's theory of cognitive development because with increase in age, there is (i) increase in the percentage of students at the formal-operational level, and (ii) decrease in the percentage of students at the concrete—operational level.

3.1.4 **Administration and Scoring of the Test and Classification of Students**

While answering the questions of this test, the students are required to put their responses on the answer-sheet (Appendix

II) Details of administering the test to a class/group have been given in Appendix III. For scoring the items and classification of students, scheme laid down by Ward et al. (1981) was followed. Concrete items are given a score of 1 and formal items a score of 2. So, the maximum possible score on this test is 42. Questions 6-11 have two correct answers. The subject is scored for success if he ticks both correct answers. Items in Part IV of the test, i.e., from 21-28 require a subject to list all possible combinations. While scoring the responses of this part, some other factors are also taken into account. If a subject has responded systematically, while attempting problems of this part, an omission or a repetition is tolerated and he is considered successful. However, item nos. 24 and 26 are scored for right answer only when responses to these items as well as to their preceding problems, i.e., item nos. 23 and 25, respectively, are correct.

Classification of subjects into different cognitive stages is made on the basis of total score on the test which is obtained by computing the sum of each subtest. The classification scheme has been presented in Table 3.7.

Table 3.7

Concrete-formal classification Scheme based on total score on Tarkik Chintan Parikshan

Classification	Score
Concrete-operational :	
Early concrete (II-A)	0—7
Late concrete (II-B)	8—22
Formal-operational :	
Early formal (III-A)	23—29
Late formal (III-B)	30—42

3.2 **Concept Attainment Tests**

Four concept attainment tests—Force, Couple, Total

Internal Reflection (TIR) and Atom—were used in the present investigation. Concept attainment tests on concepts Couple and TIR developed by Bhattacharya and Pandey (1981) and on concepts Force and Atom, edited and revised by Bhattacharya and Pandey (1985) from Asha Pandey's (1981) concept attainment tests on Force and Atom, were used. All the tests are based on the thirteen task scheme developed by Frayer, Fredrick and Klausmeier (1969). According to Carroll (1976) and Clamann (1976), this schema is suitable for wide range of concepts.

Different investigators have used different measures of concept attainment. Fredrick (1965) and Kalish (1966) used three types of error measures—exclusion errors, inclusion errors and total number of errors—based on examples and non-examples to measure concept attainment of college students for geometry concepts. Blount et al. (1967) tested achievement of grammar concepts by using a set of nine behaviours. Remstad (1969) tried to measure fifth grade children's attainment of geometric concept by means of three measures :

(i) Recognition of concept examples in a series of both examples and non-examples.

(ii) Production of a concept definition, given the name.

(iii) Production of concept example, given the name.

Concept attainment is also affected by certain other factors, such as, complexity, abstractness and perceptibility of concepts (Frayer at el., 1969). Hence, any measure of classroom concept learning should meet the following criteria :

(i) It should be applicable to various types of concepts.

(ii) It should permit differentiation of various levels of concept attainment.

(iii) It should test both, verbal and non-verbal, aspects of concept attainment.

All these above-mentioned criteria are more or less met by the Classroom Concept Learning (CCL) schema (Frayer et al., 1969). The authors identified thirteen behaviours or tasks (as referred by them), given below, which are important in evaluating the attainment of concepts.

(i) Given the name of an attribute value, select an example of the attribute.

(ii) Given an example of an attribute, select the name of the attribute.

(iii) Given the name of a concept, select the example of the concept.

(iv) Given the name of a concept, select the non-example of the concept.

(v) Given an example of the concept, select the name of the concept.

(vi) Given the name of a concept, select the relevant attribute of the concept.

(vii) Given the name of a concept, select the irrelevant attribute of the concept.

(viii) Given the definition of a concept, select the name of the concept.

(ix) Given the name of a concept, select the correct definition of the concept.

(x) Given the name of a concept, select the name of a concept supra-ordinate to it.

(xi) Given the name of a concept, select the name of a concept subordinate to it.

(xii) Given the name of two concepts, select the principle which relates them.

(xiii) Given a problem, select the correct answer by applying the principle.

Items may be constructed to test for each of these thirteen tasks. Most of the studies relating to this schema ignored the thirteenth task and items were constructed for twelve tasks.

only, a practice started by Voelker et al. (1971). This practice may suit for arts and social science concepts as done by Harris and Tabachnick (1971) and Goulb et al. (1971). However, there seems to be no reason for ignoring the thirteenth task which is an important task for science concepts.

These tasks may be viewed as thirteen steps towards total concept mastery. A general hypothesis is that just one common factor or ability underlies all the thirteen tasks. Specifically, there are five underlying abilities :

(i) Ability dealing with attributes of the concept under consideration (task nos. 1, 2, 6 and 7 in the schema)

(ii) Ability dealing with examples of the concept (task nos. 3, 4 and 5 in the schema)

(iii) Ability related to definition of a concept (task nos. 8 and 9 in the schema)

(iv) Ability related to hierarchical relationship (task nos. 10 and 11 in the schema)

(v) Ability dealing with the relationship of the concept with another concept (task nos. 12 and 13 in the schema)

Thirteen tasks of CCL schema are related to the model developed by Klausmeier dt al. (1974) for concept attainment.

3.2.1 Description of Concept Attainment Tests

Concept attainment tests on Force (Appendix V), Couple (Appendix VI) TIR (Appendix VII) and Atom (Appendix VIII) are multiple choice tests based on CCL schema incorporating thirteen behaviours for concept attainment. The concept attainment test on Couple contains twentyfour items whereas those on Force, TIR and Atom have twenty items each. Right response to each question is assigned a score of one. The maximum possible score on any test is equal to the number of items for that test. Scoring keys for these tests are given in Appendix X.

Reliability : The reliability coefficients as calculated by KR-20 for four concept attainment tests on Force, Couple, TIR and Atom are 0.63, 0.69, 0.73 and 0.71, respectively. As Harris (1968) has indicated that a test a reliability in excess of 0.50 is respectable for a group test. So, it may be concluded that these tests are fairly reliable.

Validity : To become certain upto the extent that the test measures the precise characteristics for which it has been designed, some sort of evidence is necessary which provides confidence that the test scores really represent what it appears to represent. Likewise, authors reported content and construct validities. Content validity was reported to be determined on the basis of the expert judgement. Construct validity, as reported, was determined by discriminating power of items. To ensure this, items with fairly high discriminating power were included. As Lindeman (1971, p. 89) reports, "...it is necessary that the test discriminate between students who have achieved most or all of the instructional objectives and those who have not. Furthermore, the power to differentiate between students at various achievment levels is necessary if the test is to have adequate constructs validity."

3.3 Achievement Motive Inventory

As the present investigation involved controlling the effect of achievement motive, a suitable tool to measure this was needed. For this, Achievement Motive Inventory of Gandhi and Srivastava (1982) was used. Rationale for selecting this inventory is briefly outlined in the following paragraphs :

TAT is the commonly used procedure to measure motives where responses to certain pictures are scored according to the theme of responses (McClelland et al , 1953 ; Heyns et al., 1958 ; Mehta, 1969 ; Winter, 1973). This projective technique is epecially sensitive to covert or unconscious aspects of behaviour by permitting and encouraging a wide variety of subjects' responses and by evoking unusually rich and profuse response data with a minimum of subject' awareness concerning the purpose of the test and thus providing a control for social desirability which in turn enhance its validity.

However, scientific use of such measures in research raises several critical problems. Lazarus (1961, 1966) and Shaw (1961) raised doubt as to whether the motives appear directly or inversely in the TAT. Murstein (1963) and Carney (1966) showed the extraordinary sensitiveness to the effect of immediate situation and mood in which it is taken. Klinger (1966), Weinstein (1969) and Entwis e (1972) pointed that their lack of reliability might lead to conflicting results. Actually, the lack of standardized objective scoring seems to be the major problem (Voigt and Dana, 1964) without which neither consistency estimates nor adequate normative data can be provided for and the scores have to be interpreted in idiographic rather than nomothetic form (Brown, 1970). This scoring unreliability can, though, be reduced to negligible level through extensive training but it makes such a free-respones technique highly expensive. These drawbacks coupled with difficulty in administration and scoring pose problems when used in an applied situation.

Attempts to alleviate these drawbacks led to the development of a number of objective, self-report inventories in which subjects provide descriptions or report of their own behaviour in a way that could be later scored and analyzed objectively (Edwards, 1954 ; Alpert and Haber, 1960 ; Gough 1957; Jackson, 1967 : Lynn, 1969 ; Mehta, 1969 ; Stern, 1970 ; Dutt and Sabarwal, 1973 ; Mishra and Tripathi, 1978 : Gandhi and Srivastava, 1982), Such an attempt has proved its usefulness in different fields like attitude, interests and personality inspite of low connection between language conduct, between a person says and what does. These self-report inventories seem to have convincing psychometric requirements creating a meeting ground for theoretical and practical considerations (Sundberg, 1977). It was, therefore, decided to measure achievement motive in the present study by using an objective device.

3.3.1 Description of the Inventory

The Achievement Motive Inventory of Gandhi and Srivastava (1982), used in the present study, consists of 30 items

based on ten characteristics, each having three items (Appendix XI). Each item has five alternatives and the respondents are required to choose any one of these alternatives which they feel to match with their behaviour. Characteristics included in the inventory are, Persistence (P), Personal Responsibility (PR), Aspiration Level (AL), Risk Taking (RT), Upward Mobility (UM), Time Perspective (TS), Time Perception (TP), Partner Choice (PC), Achievement Behaviour (AB) and Recognition Behaviour (RB).

Validity : The content validity of the inventory was ensured by authors by selecting items which were representative of the domain of phenomenon under consideration. The universe of the items covered was wide enough to include all aspects of achievement motive. To ensure this, they conducted extensive review of studies on achievement motive and got items scrutinized by experts in the field. Social desirability in the items was minimized by making all five alternative equally desirable, as suggested by Edwards (1954).

As the construct of achievement motive is global and consists of a number of characteristic behaviours of an individual, scores on these characteristics should be highly correlated with total scores on achievement motive inventory. All the correlations were reported to be positive and significant at 0.01 level which showed that different characteristics included in the inventory were related to total achievement motive score. This implies that probably all the characteristics indentified measure the same construct, i.e., achievement motive.

In addition, the authors validated the inventory by correlating scores on this inventory with Achievement Value and Inventory (Mehta, 1969) and against the criterion of teacher's rating of their students. They reported that Achievement Motive Inventory is a valid instrument to measure achievement motive of students.

Reliability : Test-retest reliability and rational equivalence (KR-20) were reported by authors for the inventory. Test-retest

reliability, four weeks after the first administration was reported to be 0.66 and KR-20 to be 0.79. This shows that this inventory is a reliable instrument.

Scoring : The inventory was scored on a five-point scale from 1 to 5 according to the alternative chosen by respondents for each item. Score 1 to 5 were distributed according to the alternative for each item. The item numbers in each characteristic and score for each alternative are given in the key (Appendix XII) for achievement motive inventory.

3.4 Test of General Mental Ability

For the purpose of controlling intelligence, Joshi's Group Test of General Mental Ability (1969) was used in the present investigation (Appendix XIII). This is one of the widely used intelligence test. Present investigator was only interested to control intelligence without referring to IQ, hance absence of upto date norm tables were of no concern to the investigator.

This test can be easily understood and administered within a normal class period. This test has been properly validated and standardized on large sample of children from different classess and states. The standardization sample consisted of 3867 students of the age-group 12-19 from classes eight to twelve. As the test has been standardized on the population of U.P., Bihar. M.P., Punjab, and Rajsthan, it can easily be used in Hindi speaking areas of different states. Joshi (1969) reported that there was no difference between the standardization sample of U.P. and sample from other Hindi speaking states. Hence, the test has interstate applicability. The test covers wide age-range and can discriminate between mentally superior and inferior children. It has also been found to be fairly valid when compared to other tests of intelligence.

3 4.1 Description of the Test

Joshi's (1969) test is a verbal test of general mental ability. It consists of one hundred itmes based on seven elements :

synonyms, antonyms, number series, classification, best answers, reasoning and analogies. It is aimed to measure intelligence within a limited time of 20 minutes. There is balanced item structure concering all elements in equal proportion in the first and second halves of the test in predetermined order of difficulty.

Reliability : The reliability coefficient as calculated by KR-20 is 0.883. The age and grade reliability coefficients range between 0-842, and 0.831 and 0.934, respectively.

Validity : Out of hundred items of the test, 75 items discriminate significantly at 0.01 level between highly intelligent and low intelligent group and 87 items discriminate significantly at 0.05 level. The 'g' saturation coefficients among test elements were reported to be in the range of 0.600-0.744. The residuals found from 'g' saturation coefficients among different test elements were quite negligible and insignificant. This indicates that the test is a fairly valid instrument for measuring general intellgence.

4

Design and Procedure : Part 'B' Collection of Data

This chapter deals with other parts of design and procedure except the details of adaptation and description of tools which have already been covered in the third chapter. Design of the study, sample, data collection, etc. have been suitably articulated under the following headings :

1. Design of the study
2. Sample
3. Collection of data
4. Scoring and tabulation
5. Statistical treatment

4.1 Design of the Study

The present investigation is an ex post facto research. According to Kerlinger (1983, p. 379), "Ex post facto research is systematic empirical inquiry in which the scientist does not have direct control of independent variables because their manifestations have already occurred or because they are inherently not manipulable. Inferences about relations among variables are made, without direct intervention, from concomitant variations of independent and dependent variables". In ex post facto research, direct control is not possible. A researcher can neither use experimental manipulation nor random

assignment. Owing to lack of relative control, the truth of the hypothesized relationship between variables cannot be asserted with the confidence as in experimental situation.

On the other hand, it is not possible to carry out all types researches strictly based on experimental and quasi-experimental designs. In ex post facto design, certain important variables which are known to be related to the dependent variable can be controlled statisitically and satisfactorily to bring more precision in the design and more strength to the interpretation. Present research, along with correlational study, used one way and two way (level × level factorial design having unequal cell frequencies) analysis of covariance designs. Treatment 'teaching', which was to affect concept attainment through different teaching methods and teachers, was controlled by following the same method of teaching for all the concepts and for all the schools by the investigator himself.

4.2 Sample

In ex post facto research design, it is not possible to draw random sample of subjects and assign them to different groups. The researcher is likely to draw sample keeping in view the maximum representativeness of population.

Initial problem for the present investigator was to select the institutions which exhibited the characteristics of being part of the population and could supply adequate number of subjects to form the part of the samle. The population for the main study was XI-grade science students of Varanasi city. While selecting the institutions and the sample, the investigator took consideration of whether principals and teachers would co-operate in providing necessary facilities for the administration of the tests, teaching of concepts, and allowing the investigator to visit institutions as and when required.

To draw out the sample, Incidental and Purposive Sampling Technique (Guilford, 1978) was employed. The sample was incidental because the subjects were easily available and no

question of researcher's choice arose. The sample was purposive as it mirrored the larger group, i.e , population with given characteristics. In these type of researches, incidental purposive sampling is always better than the random sampling because they solve the purpose fully without taking more strain and help in acquiring a sizeable sample in less time. This type of sample is very commonly used in psychometric studies in the West (Guilford, 1978) and has also been found to yield normal distribution of porperties among several studies made by Indian researchers (Jalota and Pandey, 1951 ; Joshi, 1960 ; Singh , 1965 ; Srivastava, 1975 ; Tandon, 1977 ; Bhattacharya, 1978). They found it to be very practical, econmical, and efficient yielding generalizable results. Many of these researchers have used this technique for constructing psychometric tests of ability.

A sample of 240 XI-grade male and female science students from four intermediate colleges of Varanasi was selected for this research. Out of these 240 students, 147 were boys and 93 girls. These 240 students were those who were present during all the activities, viz., administration of tests and teaching. The mean age of the sample was 15.51 years.

4.3 Collection of Data

To facilitate data collection, whole programme was planned ane organized in successive steps. For this, an action schedule was prepared and followed strictly in all the schools. The order followed in getting the relevant data was as follows :

(i) Administration of four Concept Attainment Tests in Physics (pre-testing).
(ii) Administration of Achievement Motive Inventory,
(iii) Administration of Test of General Mental Ability,
(iv) Administration of Tarkik Chintan Parikshan,
(v) Teaching of four concepts, viz., Force ; Couple ; TIR ; Atom, by researcher himself in succession, and

(vi) Administration of four Concept Attainment Tests in physics (post-testing) two days after teaching of each concept was over.

Before following the above schedule, an attempt was made to establish rapport with the students. They were requested to participate sincerely in the programme. Objective for this research was made clear to them. Proper care was taken to keep the testing situation free from anxiety and a conducive environment was created. Students were told that the information given by them would be kept strictly confidential and would only be used for research purpose. However, each individual would be intimated of his/her performance on each test.

Separte answersheets were provided for all the tests but responses to items on the achievement motive inventory was to be marked on the test booklet itself. Method of recording responses was printed on all test booklets. Then too, thorough verbal instructions were given. Barring the Test of General Mental Ability, all the tests were power tests. For the Test of General Mental Ability, being the speed test, proper care was taken to allow the exact time allocated for the test. Average time taken by a student, including instructions are shown below :

Four Concept Attainment Tests in Physics	—50 minutes
(For per-and post-testing)	
Achievement Motive Inventory	—25 minutes
Tarkik Chintan Parikshan	– 90 minutes
Test of General Mental Ability	approximately. —40 minutes
(Strictly 20 minutes for responding)	
Teaching of one concept	– 50 minutes

One test per day was administered. Four concept attainment tests were administered at a time whether in pre-testing or post-testing. For teaching of concepts, format developed by

Cantu and Herron (1978) wiih slight modification (Appendix XV) was followed. For this, lesson plans based on the above-said format were prepared and followed in all the schools to ensure uniformity in teaching of the concepts.

4 4 Scoring and Tabulation

At the end of data collection, the investigator had different types of data. One complete set cosisted of following types of data :

(i) Data on four Concept Attainment Tests in physics (Force, Couple, TIR, Atom) and total score (pre-testing).

(ii) Data on four Concept Attainment Tests in Physics (Force, Couple, TIR, Atom) and total score (post-testing).

(iii) Data on Tarikik Chintan Parikshan (scores on four subtests as well as total score).

(iv) Data on Test of General Mental Ability.

(v) Data on Achievement Motive Inventory.

The answersheets, containing the responses of students on the Test of Genenral Mental Ability (Appendix XIV), were scored with the help of scoring stencil given with the test manual. One point for each correct answer and zero for each wrong answer was assigned. Total score was calculated by counting the number of right answers. Concept attainment test answersheets were scored with the help of punch keys prepared for each concept (Appendix X). A score of one was given for each right answer and zero for each wrong answer. Scores for each concept and for total of these four concepts were tabulated. Tarkik Chintan Parikshan answersheets were scored with the help of the answer key Appendix IV) by assigning one point to right responses for concrete items and two points to right responses for formal intems. Scoring key for achievement motive inventory has been shown in Appendix-

XII. Score on each item ranged from 1 to 5 depending upon the alternative chosen.

The data thus obtained were tabulated on different charts. Two master charts were prepared for boys' and girls' sample. From these master charts requisite charts were then prepared for different statistical analyses.

4 5 Statistical Treatment

After data collection and scoring of answersheets, the next step was to analyze the quantitative informations so obtained using relevant statistical techniques. In addition to the general descriptive statistics, the following statistical techniques were used :

Analysis of Covariance : Concept attainment in physics of concrete-and formal-operational students was compared using analysis of covariance technique. It allowed the researcher to statistically equate the independent variable groups with respect to one or more variables which were related to the dependent variable. It allowed studying the performance of groups which were unequal with regard to an important variable as though they were equal in this respect (Popham, 1967). Analysis of covariance is frequently used when intact groups are used in place of groups that are formed by random assignment of subjects. At times, however, random assignment can be so inconvenient as to preclude experimentation altogether (Lee, 1975).

In the analysis of covariance each subject has another measure (called covariate or concomitant) associated with himself besides the score on the criterion measure. Innumerable covariates might be used in any experiment but unless one is chosen that correlates substantially with the criterion, there is little to be gained from the extra work that covariance analysis entails. The analysis of covariance is used in an attempt to adjust mean group scores to remove the bias. Although analysis of covariance has value in this context, it is

not really the solution. The technique provides a kind of equating of the groups along the covariate, but the adjustment is not perfect (Lee, 1975). In general, there are two purposes for collecting covariates and doing an analysis of covariance :

(i) to increase the power of significance tests, and

(ii) to obtain more accurate estimates of treatment means. In a specific experiment, one purpose or the other normally predominates (Lee, 1975).

In the present research, one-way analysis of covariance was used where post-test concept attainment scores were taken as criterion variable and pretest concept attainment scores, scores on test of general mental ability and achievement motive inventory as covariates.

Measurement of Interaction : Interaction refers to the combined effect of two or more variables on any dependent variable. It takes into account the combined effect of more than one variable at a time irrespective of their individual effect on the dependent variable. In the present investigation two-way analysis of covariance technique in a 3×2 factorial design, with unequal cell frequencies (Winer, 1971) was applied to measure the interaction effect of achievement motive and cognitive developmental level on concept attainment in physics.

Multiple Regression Analysis : Step-wise multiple regression analysis was carried out to find the joint and relative contribution of logical thinking, achievement motive, general intelligence and also of operational reasoning (class-inclusion, proposition, proportion and combination), achievement motive and general intelligence towards concept attainment in physics. An attempt was also made to derive a specification equation for the prediction of concept attainment through these variables.

The method of multiple regression deals with the problem of estimating a dependent variable from some combination of

a number of independent variables. In this particular study, the basic need was to select a parsimonious set of predictor variables that did a good job of estimating scores on concept attainment tests.

The only full-proof way to solve the problem was to try the variables in all possible combinations of two at a time, three at a time, and so on, but this would be prohibitively time-consuming and would provide many opportunities for taking advantage of chance. Some other complex approaches to obtain the best set of predictors for multiple correlations are given by Kerlinger and Pedhazur (1973). For the present study, a method known as step-wise multiple regression analysis was used. The chief characteristic of this method is that it include the best predictors in the regression equation, one by one, and the process stops when the variable fails to make significant contribution in accounting for the variance of the dependent variable.

Step-wise regression analysis for total score on concept attainment in physics and for score on each of the concept was carried out. The significance of the contribution made by any newly added variable in the regression equation was tested with the help of F-ratios.

Partial Correlation : To find out the relationship between operational reasoning (class-inclusion, proposition, proportion and combination) and concept attainment in physics, partial correlations were computed by partialling out the effect of general intelligence and achievement motive. Partial correlations were computed for total concept attainment scores and for scores on each concept.

When the relationship between two variables for a given group is influenced by the presence of a third variable or of a number of other variables, a measure of the relationship without this influence may be computed by the technique of partial correlation. Ideally, this problem could be avoided by

selecting only subjects who were alike with respect to the third variable. The effect of the third variable upon the relationship between the two variables being studied would thus be controlled through the research design. Unfortunately, such approaches often reduce the sample size to trivial proportions. In addition, researchers frequently conduct their investigations within an actual school environment, thereby necessiating the inclusion of intact, heterogeneous groups. For these reasons, partial correlation offers a convenient method for dealing with such problems where relationships between two variables is assessed when another variable's relationship with the initial two has been held constant or 'partialed out' (Popham, 1967).

5

Results and Discussions

With all preliminary materials having been presented, it became the onus of the researcher to present data-bound results and data-based discussions. The present investigation, consisting of many segments, refers to different aspects of total problem area. The results and discussions related to the subsidiary objective of adapting a test of Tarkik Chintan Parikshan have been presented in Chapter 3, section 3.1. Results related to major objectives and other subsidiary objective have been articulated in this chapter. As some of the subsidiary objectives have direct bearing upon the analysis of the results for main study, hence, results related to sex difference in operational reasoning and logical thinking have been presented prior to the results of the main study. Additionally, a review of studies related to sex difference in logical thinking and operational reasoning does not give a clear-cut picture. That is why before computing the data to find out the results of main objectives, an analysis for assessing the sex difference seemed essential. Results in this section have been presented as follows :

5.1 Result Related to Subsidiary Objective :

(i) Sex difference in operational reasoning

5.2 Results Related to Major Objectives :

(i) Cognitive developmental level of students

(ii) Relationship between operational reasoning and concept attainment in physics

(iii) Comparison of concept attainment in physics of concrete—and formal-operational students

(iv) Combined and relative contribution of different variables towards concept attainment in physics

(v) Interaction of achievement motive and cognitive developmental level on concept attainment in physics

5.1 Result Related to Subsidiary Objective

5.1.1 Sex Difference in Operational Reasoning

To find out significance of the difference between mean scores for boys and girls on different parts of Tarkik Chintan Parikshan (TCP), viz., Class-Inclusion (CI), Propositional Reasoning (PSR), Proportional Reasoning (PRR) and Combinatorial Reasoning (COMR), and the total score on TCP (LOTH), means, standard deviations and 't' values were computed. Results related to them with their level of significance are presented in Table 5.1.

Table 5.1

Comparison of mean scores of XI-grade boys and girls on TCP and its parts

		Boys	Girls	t	p
	n=	147	93		
1	2	3	4	5	6
	$\bar{X}$	4.26	4.19		
CI				1.61	>0.05
	δ	0.94	1.13		
	$\bar{X}$	3.52	3.51		
PSR				0.06	>0.05
	δ	0.30	2.16		

Contd. **Table 5.1**

1	2	3	4	5	6
PRR	$\bar{X}$	7.72	6.95	1.89	>0.05
	σ	3.02	3.16		
COMR	$\bar{X}$	3.32	2.69	1.74	>0.05
	σ	2.85	2.52		
LOTH	$\bar{X}$	18.83	17.33	1.61	>0.05
	σ	7.27	6.58		

Eyeballing the results in Table 5.1 shows that mean scores of boys and girls on any of the operational reasoning (CI, PSR, PRR and COMR) and on total (logical thinking) do not differ significantly. Hence, no evidence is obtained to reject the null hypothesis (Ho6) that there is no significant sex difference in operational reasoning and logical thinking. Hence, it may safely be said that present research did not reveal any sex difference in logical thinking and any of the operational reasoning.

Previous researches related to gender and intellectual development have demonstrated contradictory results. The results of this study is supported by a large number of studies (e.g., Saarni, 1973 ; Rajput, 1974 ; Waite, 1975 ; DeLuca, 1979 ; Mail, 1979 : Kelsey, 1980 ; Okeka and Wood-Robinson, 1980 ; Ehindero, 1982 ; Jain, 1982 ; Cohen, 1984 ; Work, 1984 ; Golbeck, 1986). These studies also did not find gender difference in cognitive development or operational reasoning. Some studies found significant sex differences favouring males in one reasoning pattern but not in all (Piburn, 1977 ; Brown, 1979 ; Sandhu, 1980 ; Hofstein and Mandler, 1985 ; Farrell and Farmer, 1985). Moreover, studies of Graybill (1974), Shayer and Wylam (1978), Gann (1980), Piburn (1980),

Treagust (1980), Doody (1981) Marek (1981), DeHearnandez et al. (1984), Durr (1984) and Walkotz and Yeany (1984) also reported sex difference in Piagetian reasoning.

A close examination of Piaget's theory may reveal that differences on operational reasoning and cognitive development should not be attributed to sex. According to Piaget (1964), the factors which explain the development, from one set of structures to another, are : maturation ; experience ; social transmission (linguistic transmission, education, etc.) and equilibration. Later on, Piaget (1972) said that different children also vary in terms of the areas of functioning to which they apply formal operations according to their aptitudes and their professional specializations. There are chances that boys and girls might be having varied experiences of the physical environment and differential social transmission which, in turn, could produce differing performance levels for boys and girls on Piagetian tasks. But this difference may not be attributed to sex. Before drawing any conclusion regarding gender-related differences, all other factors must be taken into consideration. If boys and girls come from same society, have same physical environment and education, one should not, on the average, expect sex difference in cognitive development and operational reasoning.

The contention that females will have more difficulty in learning abstract concepts of science (DeHernandez et al., 1984) seems unfounded on the basis of present results. Difficulty, if any, will be the same for the both saxes. To sum up, it may be pointed out that while sequencing concepts in curricula, or deciding on the methods of teaching or providing experiences to students to develop operational reasoning, there is no need to make different amount of specified effort on the basis of sex.

5.2 Results Related to Major Objectives

5.2.1. Cognitive Developmental Levels of Students

To find out the distribution of students into different deve-

lopmental levels, percentages were calculated. Table 5.2 shows the numbers and percentages of XI-grade science students functioning at different developmental levels.

Table 5.2

Distribution of XI-grade Science Students into Different Cognitive Developmental Levels

Developmental	Girls		Boys		Combined	
Level	n	%	n	%	n	%
Early concrete (II-A)	7	7.53	10	6.80	17	7.08
Late concrete (II-B	62	66.67	92	62.59	154	64.17
Early formal (III-A)	20	21.50	34	23.13	54	22.50
Late formal (III-B)	4	4.30	11	7.48	15	6.25
Total	93	100.00	147	100.00	240	100.00

Data in Table 5.2 reveal that 28.75% (22.50%+6.25%) of the eleventh grade science students are functioning at the formal level and 71.25% (7.08%+64.17%) are functioning at the concrete level. Among these, 25.80% of the girls and 30.61% of the boys are exhibiting formal thought.

This finding is at variance with the Piagetian model in respect of age at which students enter the formal-operational stage. In the present study much less students exhibited formal-operational thinking than was expected on the basis of the 11 to 15 years of age figure put forth by Piaget. The reasons for this may, though not clear, be many-fold. One possibility is that these students have simply never been provided the kinds of educational experiences which would promote formal-operational reasoning. Another reason may be that the students in the present sample may be functioning more at concrete level than those in Piaget's Geneva sample due to some fundamental differences in inherent intellectual ability. Further possibility is that the students

may be capable of formal thought but do not exhibit it in paper-pencil assessment. Perhaps a combination of some or all of these factors or some other factors not included herein contribute to low percentages of formal thinkers in the present sample.

This sample, though small in strength, is representative of eleventh grade science students and exhibits result consistent with a large number of studies for this age range conducted in different countries (e.g., Dulit, 1972 ; Renner and Stafford, 1972 ; Lawson, 1974 ; Lawson and Blake, 1976b ; Chiappetta, 1976 ; Bady, 1977 ; Lawson and Nordland, 1977 ; Kolodiy, 1977 ; Epstein, 1979 ; Billeh and Khalili, 1982 ; Jain, 1982 ; Alport, 1983 ; DeHernandez et al., 1984 ; Maiman, 1984 ; Wavering et al., 1986). These investigations concluded that a substantial proportion of high school and senior high school population functioned at the concrete level. Almost all the studies during seventies and eighties reported that not all normal subjects become fully formal by 15-16 years of age. Piaget (1972) himself realized that his Genevan subjects, with whom he worked and generalized the results, were able subjects. He stated that, "the rate at which a child progresses through the developmental succession may vary, especially from one culture to another. Different children also vary in terms of the areas of functioning to which they apply formal operations, according to their aptitudes and professional specializations". Thus, results presented in this section are also supported by Piaget's statement himself, in addition to a large number of Piagetian studies in U.S.A., U.K. and other countries. The distribution of cognitive levels in this sample are at par with samples in U.S.A., U.K. and other countries.

However, only study, Mecke and Mecke (1971), which the researcher could trace out, found a sample (of 15 year olds) who all appeared to use formal operations. In this particular study, a subject's use of formal operations was determined if he used a systematic approach to eliminate the irrelevant variables in Piaget's pendulum problem. A systematic approach is necessary, but not sufficient condition for formal

operations (Inhelder and Piaget, 1958). A person at the formal-operational level must be able to investigate the variables and then explain how they interact. Thus, Mecke and Mecke's study does not necessarily contradict other studies. It does emphasize the need for clear, workable standards for further research on formal operations. The task used, subject's previous experience and the definition of formal operations, all affect the proportion of subjects said to exhibit formal operations.

Since the results in Table 5.2 show that most eleventh grade science students are functioning at the concrete-operational level, hence, they cannot hypothesize about possibilities, separate and control variables, use proportional or correlational or combinatorial or probabilistic reasoning successfully. At the same time, what appears in most physics text-books at this grade is at a level that is conceptually too high for concrete-operational students. Conceptual schemes like atomic-molecular nature of matter, matter-energy conservation, atomic and nuclear interaction, and others are theoretical by their very nature. These schemes are abstract than observable and confirmable by direct experimental evidences gathered by the students (Good, 1977). Due to close relationship between Piaget's theory and scientific thinking, Piaget's formal-operational reasoning is called as "scientific reasoning" (Greenbowe et al., 1981). Most science courses make extensive use of proportional reasoning, controlling and separating variables, probabilistic and combinatorial reasoning, etc. For example, mechanical advantage and efficiency, gas laws, gravity, etc. are concepts which demand formal reasoning for their understanding and pose a real learning difficulty for concrete-operational students whereby genuine learning seldom occurs.

Erosion of academic standards to accommodate the large proportion of concrete-operational thinkers is obvious solution in such a situation. Certainly, this cannot be allowed. There is a need to train sciences teachers, especially in Piagetian theory and its applications in teaching-learning process and

incorporting the teaching of reasoning skills into content courses of students. Karplus (1977) has developed a learning cycle model to implement Piaget's philosophy and the teaching of reasoning in the classroom. If future students of science are expected to understand the complexities of science at higher level then science teachers must facilitate the students' development of reasoning skills as well. Such facilitatory programmes (Killian, 1979) have been developed (STAR : Steps To Abstract Reasoning, ADAPT : Accent on Developing Abstract Process of Thought, DOORS : Development of Operation Reasoning Skills). Through Piagetian-based programmes to enhance the development of reasoning skills, teachers may teach content and cognitive development simultaneously.

To sum up, it may be side that the majority of eleventh grade students (71.25%) are not adequately prepared mentally to deal with the majority of the science principles and concepts of abstract nature and teachers should make sincere efforts so that efficient mastery learning may take place.

5.2.2 Relationship between Operational Reasoning and Concept Attainment in Physics

To find out the relationship between operational reasoning and physics concept attainment, product moment correlations of post-test physics concept attainment scores with class-inclusion, propositional reasoning, proportional reasoning, combinatorial reasoning and total score on the Tarkik Chintan Parikshan (TCP) were computed. Analysis in this section were carried out for total concept attainment scores and attainment scores for each concept separately. Means, standard deviations of post-test concept attainment scores, operational reasoning, intelligence and achievement motive are given in Table 5.3.

Product moment correlation coefficients betbeen total post-test physics concept attainment scores and different aspects

of operational reasoning along with total score on TCP (logical thinking) are given in Table 5.4.

Table 5.4

Correlation Coefficients of Total Concept Attainment Scores in Physics with Operational Reasoning and Logical Thinking

	OPERATIONAL REASONING				Logical Thinking
	CI	PSR	PRR	COMR	
Total Concept Attainment	0.507	0.430	0.723	0.695	0.799
P	<0.01	<0.01	<0.01	<0.01	<0.01

n=240

Table 5.4 shows that logical thinking and different aspects of operational reasoning correlate positively and significantly with total concept attainment scores in physics. These correlations are very high (r=0.430 to 0.799).

During the past few years, a large number of studies have reported that science achievement and understanding of science concepts are significantly and positively related to the ability of students to think logically (Lawson, 1974 ; Wheeler and Kass, 1974 ; Herron, 1975 ; Lawson, Nardland and DeVito, 1975 ; Cantu and Gerron, 1978 ; McBridge and Chiappetta, 1978 ; Contessa, 1980 : Johnston, 1980 : Lutes ; 1980 ; Viravaidhaya, 1981 ; Al-Mazroe, 1982 ; Bender and Milakofsky, 1982 ; Chiappetta and Russel, 1982 ; Jacob, 1982 ; Lawson, 1982a, 1982b ; Mathur, 1982 ; Staver and Halsted, 1982 ; Tobin and Cape, 1982 ; McMeen, 1983 ; Durr, 1984 ; Farrell and Farmer, 1985 ; Niaz and Lawson, 1985 ; Tobin, 1986). The results of this study also fall in line with the above mentioned studies.

In view of the results in Table 5.4, it may be said that advancing a student's ability to reason operationally and logically may improve his attainment of physics concepts.

This result, however, may be interpreted in a different way also. Observed correlations of physics concept attainment with different aspects of operational reasoning and logical thinking ability may not be due to concept attainment's dependence upon operational reasoning, rather due to the co-dependence of both operational reasoning and physics concept attainment on some general intelligence factor, perhaps, what Spearman (1951) has called subject's innate educative ability or "g" factor, or what Cattell (1971) referred as fluid intelligence. This contention requires that students high in general intelligence will perform well on both formal-operational reasoning tasks and concept attainment tests because of their co-dependence on some basic and fixed intelligence factor or factors. Some support for this statement comes from studies by DeVries (1974), Keating (1975) and Cloutier and Goldschmid (1976) who have shown formal reasoning and various measures of intelligence to be correlated.

If correlations between different aspects of operational reasoning along with logical thinking and physics concept attainment are computed with the influence of general intelligence partialled out and the resultant correlations thus computed drop to a non-significant level, then this alternative possibility gets strengthened. In that case, the observed correlations of operational reasoning and logical thinking with physics concept attainment may be said to be due to their co-dependence on general intelligence. However, if the correlations remain substantial, then support for the statement that ability to reason operationally does significantly influence physics concept attainment gets support and in such a case it may be said that improving one's operational reasoning will improve his attainment of physics concepts.

In order to get a clear picture, out of above discussions, partial correlation were computed by holding constant the

influence of general intelligence. Table 5.5 shows product moment correlation coefficients of general intelligence with post-test concept attainmet scores, operational reasoning and logical thinking. Results related to partial correlations are given in Table 5.6.

Table 5.5

Product Moment Correlation Coefficients of General Intelligence with Total Concept Attainment, Operational Reasoning and Logical thinking

	Total Concept Attain-ment	OPERATIONAL REASONIG				Logical Thinking
		CI	PSR	PRR	COMR	
Intelli-gence	0.695	0.480	0.402	0.570	0.540	0.658
P	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

n=240

Table 5.6

First Order Partial Correlation Coefficients of Total Concept Attainment with Operational Reasoning and Logical thinking after holding general Intelligence Constant

	OPERATIONAL REASONING				Logical Thinking
	CI	PSR	PRR	COMR	
Total Concept Attainment	0.275	0.229	0.553	0.529	0.630
p	<0.01	<0.01	<0.01	<0.01	<0.01

n=240

Table 5.6 shows that partial correlation coefficients between different aspects of operational reasoning and physics concept attainment having held the effect of general intelligence constant vary between 0 229 to 0.553 for XI-grade science students. Further, partial correlation between total scores of operational reasoning (logical thinking) and physics concept attainment scores for these students is 0.630 ($p<0.01$).

Partial correlation coefficients of different aspects of operational reasoning and logical thinking with concept attainment in physics, having the effect of general intelligence partialled out, are substantially lower than the correlation coefficients in Table 5.4. This indicates that high correlation between Piagetian reasoning and physics concept attainment is somewhat due to confounding effect of general intelligence. However, the presence of substantial correlations after partialling out the effect of general intelligence, indicates that the original correlations are not wholly dependent upon intelligence.

Having analyzed the data after partialling out the effect of general intelligence, next variable to be partialled out is achievement motive. Review of Studies reveals that achievement motive affects academic achievement and has been shown to correlate substantially with physics concept attainment (Pandey, N.N., 1981; Rai, 1984). Table 5.7 shows that achievement motive correlates positively and significantly with physics concept attainment, different aspects of operational reasoning and their total (logical thinking) and general intelligence.

To get a better picture of the relationship between physics concept attainment and operational reasoning, second order partial correlations were computed, having the influence of general intelligence and achievement motive partialled out. Table 5.8 shows second order partial correlation coefficients of total concept attainment in physics with different aspects of operational reasoning and their total (logical thinking) having held the effects of general intelligence and achievement motive constant.

Teble 5.7

Product Moment Correlation Coefficients of Achievement Motive with Concept Attainment, Operational Reasoning, Logical Thinking and General Intelligence

	Total Concept Attainment	OPERATIONAL REASONING				Logical Thinking	General Intelligence
		CI	PSR	PRR	COMR		
Achievement motive	0.487	0.359	0.221	0.386	0.323	0.417	0.497
p	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

n=240

Table 5.8

Second Order Partial Correlation Coefficients of Total Concept Attainment with Operational Reasoning and Logical Thinking after holding Constant General Intelligence and Achievement Motive

	OPERATIONAL REASONING				Logical Thinking
	CI	PSR	PRR	COMR	
Total Concept Attainment	0.248	0.229	0.540	0.527	0.621
p	<0.01	<0.01	<0.01	<0.01	<0.01

n=240

Results in Table 5.8 show that correlations of concept attainment in physics with different aspects of operational

reasoning and logical thinking vary between 0.229 to 0.621. All these second order partial correlation coefficients are positive and significant at 0.01 level of significance. Thus, the statistical null hypothesis of no significant relationship of concept attainment in physics with different aspects of operational reasoning and logical thinking (Ho 1: a) is not tenable. These results make clear that class-inclusion, propositional reasoning, proportional reasoning and combinatorial reasoning singly or in combination (logical thinking) affect the concept attainment in physics significantly even if the effects of general intelligence and achievement motive are partialled out.

Partial correlation coefficients of different aspects of operational reasoning and logical thinking scores with total concept attainment scores in physics, having the effect of general intelligence and achievement motive partialled out came in the range of 0.229 to 0.621. Comparison of these correlations with those in Table 5.6, first order partial correlation coefficients after holding the effect of general intelligence constant, reveals that achievement motive makes only nominal effect on the size of the first order partial correlation coefficients. This means that original correlations are more dependent upon general intelligence than on achievement motive.

The correlations in Table 5.4, prior to partialling out the effect of general intelligence and achievement motive, are pretty high. Other investigators also obtained similar results between Piagetian reasoning and various measures of achievement. Hammond (1974) obtained a correlation of 0.80 between scores on the battery of Piagetian tasks and the total points earned in chemistry course. Lawson (1980) reported very high correlation ($r=0.75$, $p<0.001$) between scores on Piagetian demonstration test and cumulative examination score. With field-dependence/field-independence partialled out this came down to 0.53. Lawson (1982b), in another study, found correlations in the range of 0.58 to 0.69 between various measures of formal reasoning and science achievement for ninth grade students. For college students, he reported a

correlation of 0.56 between biology achievement and formal reasoning. When fluid intelligence was partialled out, it came out to be 0.51. Raven and Polanski (1974), Raven and Calvey (1977), Howe and Early (1979) and Lawson (1982a) have reported correlations in the range of 0.49 to 0.67 between science achievement and Piagetian reasoning.

Two interpretations of high correlations, obtained in this study, may be advanced. As students progress from concrete to transitional to formal operations, they acquire skills and possess an increased verbal and symbolic capacity. Second, the concept attainment test instruments contain some items that require operational reasoning for their solution which leads to anticipation that students scoring high on formal-operational reasoning items would score high on concept attainment tests in physics.

To conclude, it may be said that Piagetian measures of operational reasoning and logical thinking abilities are significantly related to concept attainment in physics has been confirmed for this specific sample. The investigator has no reason to suspect that in other samples of higher secondary students similar positive correlations would not be found. The results in this section lend strong support to the comments of Chiappetta (1976) that logical thinking ability is an underlying factor that strongly influences the learning of a great deal of the course content in the science curriculum.

5.2.2.1 Relationship between Operational Reasoning and Concept Attainment in Physics : Results Related to each Concept

This section deals with results of relationship between operational reasoning and concept attainment in physics for each concept separately. Table 5.9 shows product moment correlation coefficients between operational reasoning, i.e., class-inclusion (CI) ; propositional reasoning (PSR) ; proportional reasoning (PRR) ; combinatorial reasoning (COMR),

their total (logical thinking) and concept attainment in physics for each concept separately.

Table 5.9

Product Moment Correlation Coefficients of Concept Attainment in Physics with Operational Reasoning and Logical Thinking for each Concept Separately

Concept Attainment	OPERATIONAL REASONING				Logical Thinking
	CI	PSR	PRR	COMR	
Force*	0.516	0.349	0.603	0.618	0.691
Couple	0.373	0.354	0.613	0.589	0.665
T I R	0.398	0.380	0.618	0.629	0.695
Atom	0.477	0.408	0.678	0.584	0.724

n=240

*All correlations are significant at 0.01 level

Table 5.9 makes it clear that class-inclusion, proposition, proportion, combination and logical thinking correlate positively and significantly with concept attainment scores in physics for each concept separately. All the correlation coefficients are substantial which means that a strong relationship exists between different aspects of operational reasoning, their total and concept for each concept. This indicates that the concepts, taken in this study, exhibit nearly same nature of abstractness and require all reasoning operations.

In order to get a more definite picture of the relationship, it was considered worthwhile to hold constant the effects of general intelligence and achievement motive. First order partial correlation coefficients were computed between different aspects of operational reasoning and post-test concept attain-

ment scores for each concept by holding the effect of general intelligence constant. Then, second order partial correlation coefficients were computed by holding the effect of achievement motive constant in addition to general intelligence. Table 5.10 shows product moment correlation coefficients of post-test concept attainment scores in each concept with general intelligence and achievement motive.

Table 5.10

Product Moment Correlation Coefficients of General Intelligonce and Achievement Motive with Post-test Concept Attainment Scores on each Concept

	Int	A.M.	Force	Couple	TIR	Atom
Int.*	—	0.497	0.582	0.606	0.591	0.639
A.M.		—	0.429	0.439	0.391	0.432

n=240

*All correlations are significant at 0.01 level.

Table 5.11

First Order Partial Correlation Coefficients of Concept Attainment Scores in each Concept with Operational Reasoning and Logical Thinking after holding General Intelligence Constant

Concept Attainment	OPERATIONAL REASONING				Logical Thinking
	CI	PSR	PRR	COMR	
Force	0.333*	0.155**	0.406*	0.444*	0.504*
Couple	0.118	0.151**	0.410*	0.391*	0.445*
T I R	0.162**	0.193*	0.423*	0.456*	0.505*
Atom	0.252*	0.214*	0.496*	0.368*	0.524*

n=240

$^*p < 0.01$, $^{**}p < 0.05$

First order partial correlation coefficients are given in Table 5.11, whereas Table 5.12 depicts second order partial correlation coefficients.

Results in Table 5.11 reveal that all correlation coefficients are significant except one. The non-significant relationship is between class-inclusion and concept Couple. Correlation coefficients between class-inclusion and the concept TIR, between propositional reasoning and concepts Force and Couple are significant at 0 05 level of significance, whereas the rest are significant at 0.01 level of significance. These results make it clear that logical thinking plays a major role in the attainment of different physics concepts used in the study as different aspects and total of operational reasoning correlate positively and significantly with all concept attainment tests even after the effect of general intelligence partialled out. When subtests of TCP are considered, it is found that proportional reasoning and combinatorial reasoning affect substantially the performance on all the concepts as the correlations came out to be in the range of 0.368 to 0.496. Propositional reasoning also, significantly affects the performance but not as mush as proportional or combinatorial reasoning because correlations are not substantial. Correlations of four concept attainment tests with class-inclusion give interesting results. Performance of eleventh grade science students on three concepts, viz., Force, TIR and Atom, is significantly influenced by class-inclusion whereas with Couple it yields an insignificant relationship. This result may be explained by looking into the nature of test items on concepts Couple and TIR. Majority of items in tests based on these concepts are of abstract nature whereas all the items in the subtest class-inclusion of TCP demand concrete reasoning. In such a situation either non-significant or low correlation is expected.

The second thing, which results in Table 5.11 reveal, is that the correlations of proportional reasoning, combinatorial reasoning and the total score on TCP (Logical thinking) with concept attainment scores in different concepts are not wholly due to the co-dependence of these variables on general intelli-

gence, because substantial correlations remain even after partialling out the effect of general intelligence. However, a substantial correlation does not remain when effect of general intelligence is held constant for correlations of class-inclusion and propositional reasoning with all the concepts. It may be said that much of the correlation between these variables was due to co-dependence of these variables on general intelligence.

The next variable to be partialled out is achievement motive. Tables 5.7 and 5.10 depict that this variable correlates significanty with general intelligence, different aspects of operational reasoning and logical thinking and concept attainment score on each concept separately. It might be proposed that observed correlations are due to co-dependence of operational reasoning and physics concept attainment on achievement motive also. To verify this proposition, second order partial correlation coefficients were computed with the effect of general intelligence and achievement motive held constant. These correlations are presented in Table 5.12.

Table 5.12

Second order Partial Correlation Coefficients of different aspects of Operational Reasoning and Logical Thinking with Concept Attainment in each Concept after holding Constant General Intelligence and Achievement Motive

Concept Attainment	OPERATIONAL REASONING				Logical Thinking
	CI	PSR	PRR	COMR	
Force	0.311*	0.153**	0.389*	0.439*	0.491*
Couple	0.089	0.149**	0.393*	0.385*	0.430*
T I R	0.143**	0.192*	0.412*	0.452*	0.495*
Atom	0.231*	0.213*	0.483*	0.362*	0.513*

n=240

*p < 0.01, **p < 0.05

Results in Table 5.12 show that correlations of concept attainment with different aspects of operational reasoning and logical thinking vary between 0.153 to 0.491 for concept Force, 0 089 to 0.430 for concept Couple, 0.143 to 0.495 for concept TIR and 0.213 to 0.513 for concept Atom. All these second order partial correlations are positive and significant except that between class-inclusion and concept attainment in Couple. Thus, statistical null hypotheses of no significant relationship of different aspects of operational reasoning (class-inclusion, propositional reasoning, proportional reasoning, combinatorial reasoning) and logical thinking with concept attainment scores in concept :

(i) Force (Hol : b),

(ii) Total Internal Reflection (Hol : d) and Atom (Hol : e) are not tenable.

However, in view of the significant correlation of logical thinking and three aspects of operational reasoning (PSR, PRR, COMR) with concept attainment scores in concept couple and non-significant correlation between class-inclusion and concept attainment scores in concept Couple, the condition for retaining or not retaining the null hypothesis Hol : C is not in the same pattern of Hol : b, d, e. So, in the light of results in Table 5 12, hypothesis Hol : C is not tenable for propositional reasoning, proportional reasoning, combinatorial reasoning and logical thinking but the same is retained for class-inclusion.

Above results are similar to those reported in Table 5.11. This shows that correlations obtained after partialling out general intelligence (Table 5.11) are not due to the co-dependence of correlated variables (operational reasoning and concept attainment) on achievement motive because correlation co-efficients are lowered only nominally and no change in their significance level did occur.

From these results, it may be inferred that proportional

reasoning, combinatorial reasoning and logical thinking strongly correlate with physics concept attainment scores for each concept separately. Propositional reasoning, also, correlates significantly with concept attainment scores for each concept, but these correlations are low. The correlation for propositional reasoning with concept Atom reveals that propositional reasoning is more important for concept Atom than other three concepts. Class-inclusion seems important for concept Force and Atom because correlation coefficients are signifficant ($p < 0.01$) even after partialling out the effects of general intelligence and achievement motive. Although, it yields a significant correlation ($p < 0.05$) with concept TIR, it does not seem important to that extent because of low correlation. And for the attainment of the concept Couple it does not make any difference.

Consistently high correlations of proportional reasoning and combinatorial reasoning, in particular, and logical thinking, in general, with all the physics concepts, selected for this study, suggest that they are very important for better performance in physics concepts. The classroom teacher and the curriculum developers must have an understanding of the reasoning of students and reasoning demands of physics concepts. It is important to know how much of what is to be taught in physics at higher secondary level requires formal thought and which aspect of reasoning more, and why and which concepts pose difficulty in their understanding and how to overcome these difficulties. Whether it can be done by providing students opportunities to use formal thought, or by bringing changes in teaching methods keeping in view the nature of concepts and students' reasoning level, or in some other way, are matters of further research.

To conclude, it may be said that proportional and combinatorial reasoning, in particular, and logical thinking, in general, seem to be important variables for concept attainment in physics for XI-grade science students.

5.2.3 Comparison of Concept Attainment in Physics of Concrete-and Formal-Operational Students

Comparison of Concept attainment in physics of concrete-and formal-operational students was made by computing the significance of difference in their mean post-test concept attainment scores. Discussions in section 1.4 of Chapter 1 shows that science achievement is affected by initial knowledge, general intelligence and achievement motive and teaching methods. Results in Table 5.13 also show that post-test concept attainment in physics is significantly and positively related to initial knowledge in physics (pre-test concept attainment in physics), achievement motive and general intelligence for total concept attainment as well as for concept attainment in each concept separately.

Table 5.13

Correlation coefficients of post-test concept attainment with respective pre-test concept attainment, general intelligence and achievement motive

	Pretest Concept Attainment	General Intelligence	Achievement Motive
Force*	0.649	0.582	0.429
Couple	0.597	0.606	0.440
T I R	0.566	0 591	0.391
Atom	0.784	0.640	0.432
Total	0.828	0.695	0.487

n=240

*All correlations are significant at 0.01 level.

One-way analysis of covariance with three covariates, viz., pretest concept attainment, achievement motive and general intelligence, was used to test the null hypothesis that there is no significant difference in the post-test physics concept attain-

ment of concrete and formal students. Results related to this analysis are presented in Tables 5.14, 5.15 for total concept attainment. Means and standard deviations of criterion (posttest scores) and controls (pre-test, achievement motive and general intelligence) are shown in Table 5.14. Table 5.15 depicts the summary of analysis of covariance.

Table 5.14

Mean and SD of criterion (total concept attainment) and control variables for concrete and formal thinkers

Cognitive dev. level	n	Criterion Post-test	Controls Pretest	Ach. Mot.	Gen. Int.
Concrete	171	49.34	39.72	111.01	50.47
		(9.97)	(8.84)	(10.09)	(11.79)
Formal	69	68.19	49.96	116.45	64.57
		(6.54)	(8.01)	(8.37)	(10 51)
Total	240	54.76	42.66	112.57	54.52
		(12.49)	(9.77)	(9.93)	(13.09)

Table 5.15

Summary of ANCOVA for total concept attainment

Source of variation	SS	df	MSS	F	p
Between	2959 65	1	2959.65	108.89	<0.01
Within	6387.23	235	27.18		
Total	9346.88	236			

Results in Table 5.15 indicate that concrete and formal thinkers differ significantly in their mean physics concept attainment scores ($F=108.89$, $p<0.01$) when initial differences between the two groups have been adjusted with respect to

prior knowledge in physics, general intelligence and achievement motive. The adjusted mean scores for concrete-and formal-operational groups are 52.12 and 61.29, respectively. This shows that formal-operational students outperform their concrete-operational counterparts and thus the null hypothesis of no significant difference between mean concept attainment scores of concrete and formal thinkers (Ho2 : a) is not tenable.

This result is in congruence with large number of studies conducted in various countries for science achievement and understanding of science concepts (Lawson and Renner, 1975 ; Cantu and Herron, 1978 ; Cobern, 1979 ; Holden, 1979 ; Howe and Early, 1979 ; Lybeck, 1979 ; Schroeder, 1979 ; Stephenson, 1979 ; Ward, 1979 ; Lutes, 1980 ; Piburn, 1980 ; Ward and Herron, 1980 ; McVey, 1981 ; Shayer and Wylam, 1981 ; Bass and Maddux, 1982 ; Vaidya, 1982 ; Crenshaw, 1983 ; Mulopo, 1983 ; Yeany and Porter, 1983 ; Milka, 1984 ; Hofstein and Mandler, 1985, Abraham and Renner, 1986) and adds to an increasing body of evidence which points out that formal-operational subjects perform significantly better than concrete-operational subjects on science achievement measures.

The researcher could not trace out a single study which used previous knowledge in physics, general intelligence and achievement motive, all three as covariates at a time in order to make both groups equal with respect to these three variables. Significant and substantial correlations (Table 5.13) between criterion post-test concept attainment scores in physics and covariates suggest that they affect physics concept attainment and controlling them is necessary. Now, in view of adjusting the two groups for initial differences in above mentioned variables, it is hard to believe that the difference in physics concept attainment may not be due to the difference in intellectual development of students. Although, in a design of the present type, it is not possible to control all variables, but if some important concomitants are controlled, then a significant F-ratio suggests that the difference in performance is due to the difference in independent variable, such as,

cognitive developmental level of students as in the present study.

Results in this section suggest that the factual and conceptual knowledge which the students have acquired, is associated with the operational level they have entered. The formal-operational students possess greater capacity to acquire knowledge than the concrete-operational students. Students at the concrete-operational level find themselves confronted with problems when formal thought is required to attain concepts. They either turn to some other activity, or memorize an algorithm that may work sometimes.

In the light of this result, it may appear that physics courses at higher secondary level should be so designed to minimize the need for formal thought. However, this reasoning is frightening. Herron (1978) points out that instead of trying to eliminate the need for formal thought, curricula should be so designed to provide many opportunities for students to apply formal-operational reasoning. These opportunities should be interpersed with a lot of concrete experiences of the type which support these activities that require formal thought. The curriculum should be so designed that students return frequently to the same kind of formal-operational thought in new contexts and teachers constantly encourage students faltering efforts. However, much research is needed in order to provide answer of mixing of formal and concrete activities to be included in the courses.

To conclude, it may be said that students who are classified as formal-operational on the basis of their scores on the Tarkik Chintan Parikshan (TCP) are likely to achieve significantly more than students who are classified as concrete-operational.

5.2.3.1 Comparison of Concept Attainment in Physics of Concrete-and Formal-Operational Students : Results Related to Each Concept

After observing the effect of concrete-and formal-opera-

tional thinking on total concept attainment in physics, further analyses were carried out for each concept, separately. Results related to these analyses are presented in Tables 5.16 and 5.17. Table 5.16 shows means and standard deviations of criterion and one control variable (pretest concept attainment) for all the four concepts. Means and standard deviations of other two controls, i.e., achievement motive and general intelligence have already been given in Table 5.14. They were not produced here as that will be sheer repetition of data. Results of analysis of covariance are presented in Table 5.17.

Table 5.16

Mean and SD of post-test and pretest concept attainment scores for concrete and formal thinkers

Cognitive dev. level		n	CONCEPTS			
			Force	Couple	TIR	Atom
	Post-test		11.74 (3.04)	13.65 (3.30)	11.63 (2 89)	12.35 (3.31)
Concrete		171				
	Pretest		9.36 (3.08)	10.93 (2.99)	8.71 (2.96)	10.74 (3.52)
	Post-test		15.88 (1.93)	18.51 (2.81)	16.61 (1.90)	17.19 (1.80)
Formal		69				
	Pretest		11.39 (2.51)	13.09 (3.32)	11.17 (3.01)	14.30 (2.66)
	Post-test		12.93 (3.35)	15.05 (3.85)	13.06 (3.48)	13.74 (3 68)
Total		240				
	Pretest		9.95 (3.06)	11.55 (3.23)	9.42 (3.17)	11.76 (3.67)

Table 5.17

Summary of ANCOVA for attainment of each concept

Concept	Source of variation	SS	df	MSS	F	p
F						
O	Between	264.58	1	264.58		
R					56.49	<0.01
C	Within	1100.67	235	4.68		
E	Total	1165.25	236			
C						
O	Between	252.21	1	252.21		
U					41.92	<0.01
P	Within	1414.01	235	6.02		
L	Total	1666.22	236			
E						
T	Between	304.38	1	304.38		
					66.58	<0.01
I	Within	1074.42	235	4.57		
R	Total	1378.80	236			
A	Between	130.53	1	130.53		
T					38.40	<0.01
O	Within	798.84	235	3.40		
M	Total	929.37	236			

Results in Table 5.17 make it clear that mean post-test concept attainment scores of concrete-and formal-operational XI-grade science students differ significantly for each concept ($F=56.49$ for concept Force, $F=41.92$ for concept Couple, $F=66.58$ for concept Total Internal Reflection, $F=38.40$ for concept Atom ; for all F, $p<0.01$), when both groups have been made equal with respect to previous knowledge of respective physics concepts, general intelligence and achievement motive. The adjusted mean concept attainment scores for concrete and formal students are 12.17 and 14.82 for the

concept Force, 14.29 and 16.91 for the concept Couple, 12.22 and 15.16 for the concept TIR and 13.19 and 15.10 for the concept Atom, respectively. This simply suggests that formal-operational students perform significantly better than their concrete-operational counterparts on all the four concepts separately also and thus the null hypotheses of no significant difference between mean concept attainment scores of concrete and formal thinkers (Ho2 : b, c, d, e) are not tenable.

An analysis of science concepts used in this study reveals that there is absence of direct examples which can be shown to students or the examples which can be shown to reveal the characteristics of the concept that give it meaning and such concepts pose difficulty in understanding to concrete-operational students For example, an example of "atom" cannot be shown to students because atoms are too small ; even if one can show an example of "element", the example does not reveal the critical characteristics that an element is composed of one kind of atom. Since concrete-operational students rely on concrete experience and encounter difficulty in identifying possibilities and using "if-then" reasoning, so they will find it difficult to understand those concepts which do not have perceptible examples and attributes. On the other hand, formal-operational students who are capable of hypothetical thought, can hypothesize and learn such concepts more readily than subjects who rely on concrete reasoning. This contention draws its support from the results in this sub-section. There seems no theoretical basis to believe that formal-operational students will perform better on concepts that have perceptible examples and attributes (concrete concepts) than concrete-operational students. It might be possible that concrete-operational students have not been able to following the instructions at par with formal-operational students, even for attributes which has concrete examples. This might have tended to lower the performance of concrete-operational students.

At this stage, it would be worthwhile to consider the comments of Ward and Herron (1980). They comment that

anything approaching a "pure" test of intellectual activity probably does not exist. They further said that, even though the Longeot Test of Cognitive Development described as a test of intellectual development appeared to measure intellectual development in the Piagetian sense, scores on the test were undoubtedly influenced by other factors : reading ability, test "wiseness", possession of certain factual information, familiarity with particular problem format, and motivation, to mention just few. Similar factors also affect performance on the criterion measure and learning in the class. It is likely that students who are classified as concrete-operational have certain learning difficulties which operate to lower their performance even on the test items that require no more advanced intellectual skills than they possess. They hypothesized that the difference in performance between formal-and concrete-operational students may be due to other factors than only the level of intellectual development. Results of this study somewhat dispute their hypothesis. In this study, statistical control for three important variables, prior physics knowledge, general intelligence and achievement motive in addition to teaching method was made and then also, the investigator obtained significant and substantial F-ratio for all concepts. So, the researcher may say that the difference in performance is mainly due to the difference in cognitive developmental level of students.

This result also suggests that it may be possible to use Piaget's theory to identify concepts which are likely to be difficult for concrete-operational students to learn. Knowing this, one may either restructure courses to postpone such concepts for the time being or take measures to enhance cognitive developmental level. But how to make formal concepts understandable to concrete-operational students is a subject of further research. However, cognitive development should be an educational goal of highest priority for the classroom teacher.

To conclude, it may be said that students who are operating at the concrete-operational level of intellectual development

suffer a disadvantage when compared to their formal-operational classmates, in success of performance on physics concepts.

5.2.4 Combined and Relative Contribution of Different Variables Towards Concept Attainment in Physics

Having found the relationship of concept attainment in physics with different aspects of operational reasoning and logical thinking ability, the problem arises of its prediction. Concept attainment, being a complex process, is the product of a number of variables. Motives interact complexly to affect concept attainment, whereas operational reasoning and logical thinking ability, on the other hand, determine the level of concept attainment as is clear from review of literature and results in sections 5.2.2 and 5.2.2.1. As such a need was felt to pull all these pieces together in order to predict concept attainment in physics. This task is usually accomplished in a stepwise manner (Cooley and Lohnes, 1971 ; Kerlinger and Pedhazur, 1973 ; Nie et al., 1975).

One approach starts with a single predictor variable that yields the highest correlation coefficient with criterion measure and then successive predictors are added until a statistical point is reached beyond which remaining predictors do not add a statistically significant increment to the amount of variance accounted for in the criterion variable. This incremental or accretion method is sometimes called the forward solution. A second approach begins with the total composite of predictors and successively drops from it those predictor variables, the omission of which, in the investigator's judgement, does not reduce the size of 'R' substantially, or decrease it to a statistically significant degree. This method is the decremental or deletion method that is sometimes labelled as the backward solution. Customarily, the two methods lead to somewhat different results, although the practical difference in outcomes can be trivial.

In order to establish a regression equation to predict concept attainment in physics on the basis of knowledge of

scores on different aspects of operational reasoning, general intelligence and achievement motive, step-wise multiple regression analysis was used. This procedure was utilized successfully with scores in all the concepts, viz., Force, Couple, TIR and Atoms, along with the total scores in these four concepts, as dependent variables. Scores on TCP, general mental ability test and achievement motive inventory were used as independent variables. For each concept and for total scores in these concepts, two sets of predictors, as specified below, were used :

Predictor Variables	**Criterion Variable**
(i) Logical thinking (LOTH) General intelligence (INT) Achievement Motive (AM)	
Class-inclusion (CI) Propositional reasoning (PSR) Proportional reasoning (PRR)	Post-test Concept Attainment in Physics (CAP)
(ii) Combinatorial reasoning (COMR) General intelligence (INT) Achievement motive (AM)	

As this multiple regression problem involved four and seven variables for two sets, to arrive at different specification equations it naturally became time consuming. The data were, therefore, computerized at the computer centre of Banaras Hindu University, Varanasi. Steps involved in the computer analysis were as follows :

—derivation of intercorrelation matrix
—determination of beta weights
—calculation of multiple correlation
—determination of b-weights and intercept constant.

All the results in this analysis have been presented for total concept attainment and then for each concept. Intercorrelation matrices of total concept attainment scores and scores in

each concept with predictor variables are presented in Table 5.18.

Table 5.18

Intercorrelation matrix of criterion and predictor variables

		CAP	CI	PSR	PRR	COMR	LOTH	INT	AM
	CAP	—	.507	.430	.723	.695	.799	.695	.487
T	CI		—	.305	.490	.440	.628	.480	.359
O	PSR			—	.423	.318	.674	.402	.221
T	PRR				—	.567	.866	.570	.386
A	COMR					—	.804	.540	.323
L	LOTH						—	.658	.417
	INT							—	.497
Force : CAP			.517	.349	.603	.618	.691	.582	.429
Couple : CAP			.373	.354	.613	.589	.665	.606	.439
TIR : CAP			.398	.380	.618	.629	.695	.591	.391
Atom : CAP			.477	.408	.678	.584	.724	.640	.433

Results related to multiple correlations, b-weights and contribution of each predictor variable to total variance for total concept attainment and for individual concepts have been dealt in following sub-sections.

5.2.4.1 Regression of Total Concept Attainment on Logical Thinking, General Intelligence and Achievement Motive

Results related to prediction of total concept attainment in physics are shown in Table 5.19. The F-ratio, for addition of each variable in the regression equation, was calculated by the following formula (Thomson, 1951) :

$$F = \frac{(R^2_n - R^2_{n-1})\,(N-n-1)}{1-R^2_n}$$

where,

R^2_n = square of multiple correlation after adding nth test,

R^2_{n-1}=square of multiple correlation of (n−1) tests before adding *n*th test, and

N=total number of subjects.

Table 5.19

Summary of multiple regression analysis for the prediction of total concept attainment scores having logical thinking, general intelligence and achievement motive as predictors

Variable added	r	b-weight	Cumulative R	R^2	Variance	R	p
LOTH	0.799	1.0359	0.799	0.6384	63.84	420.19	<0.01
INT	0.695	0.2401	0.830	0.6889	5.05	38.47	<0.01
AM	0.487	0.1497	0.836	0.6989	1.00	7.83	<0.01

n=240

Table 5.19 shows that the cumulative multiple correlation for the derived regression equation is 0.836 which is significant at 0.01 level. This indicates that 69.89% (R^2) of the variance in total concept attainment in physics for XI-grade science students has been covered by these three (LOTH, INT and AM) predictor variables. It is evident from Table 5.19 that F-ratios for all the three tests are significant at 0.01 level of significance, meaning thereby that they have contributed significantly for the prediction of physics concept attainment. Hence, the hypothesis Ho3 : a that logical thinking, general intelligence and achievement motive do not account for significant amount of variance in total concept attainment scores in physics is not accepted. Lion share of the total variance covered by predictor variables is that of logical thinking (63.84%). Further additions of 5.05 per cent and 1.00 per cent was made by intelligence and achievement motive, respectively.

Table 5.19 ultimately helped in presenting a coherent picture of the results by arriving at the specification equation

for the prediction of total concept attainment in physics, which may be written in raw score form as follows :

$$Y' = 5.9098 + 1.0359 \text{ LOTH} + 0.2401 \text{ INT} + 0.1497 \text{ AM}$$

where,

Y′=predicted total concept attainment score in physics,
LOTH=raw score on TCP,
INT=raw score on the test of general mental ability,
AM=raw score on the achievement motive inventory, and 5.9098 is the intercept term.

Above equation shows that for predicting total concept attainment in physics for any student on the basis of predictor variables studied, his raw scores on these variables should be multiplied by b-weights assigned to them and then added or subtracted according to the signs attached to the weights, implying whether it helps or hinders in prediction. Finally, the intercept constant value (5.9098 here) should be added to ensure that the mean of the predicted variable (Y′) coincides with the mean of the observed value.

The magnitude of this relationship is such that the contention that logical thinking ability is an underlying intellectual factor associated with physics concept attainment cannot be rejected. The fact that logical thinking accounted for more variation in physics concept attainment than general intelligence and achievement motive demonstrates that it has more influence on concept attainment in physics than the later two.

5.2.4.2 Regression of Total Concept Attainment on Different Aspects of Operational Reasoning, General Intelligence and Achievement Motive

Results related to the prediction of total concept attainment scores in physics through different aspects of operational reasoning, i.e., class-inclusion, proposition, proportion and combination, along with general intelligence and achievement motive are shown in Table 5.20.

Table 5.20

Summary of multiple regression analysis for the prediction of total concept attainment scores having different aspects of operational reasoning, general intelligence and achievement motive as predictors

Variable added	r	b-weight	Cumulative R	R^2	% variance	F	p
PRR	0.723	1.2878	0.723	0.5227	52.27	260.67	<0.01
COMR	0.695	1.4062	0.802	0.6432	12.05	80.02	<0.01
INT	0.695	0.2360	0.839	0.7039	6.07	48.40	<0.01
AM	0.487	0.1452	0.845	0.7140	1.01	8.30	<0.01
PSR	0.430	0.3397	0.847	0.7174	0.34	2.80	<0.05
CI	0.507	0.4433	0.847	0.7174	—	—	—

n=240

Table 5.20 shows that F-ratios for four tests, viz., proportional reasoning, combinatorial reasoning, general intelligence and achievement motive are significant at 0.01 level of significance whereas for propositional reasoning it is significant at 0.05 level of significance. Out of these five variables all of which contribute significantly towards the prediction of criterion score, major shares go to proportional reasoning (52.27%), combinatorial reasoning (12.05%) and general intelligence (6.07%). Contribution of achievement motive and propositional reasoning, though significant is small (1.01% and 0.34%, respectively). Thus, the total variance accounted by the combination of five variables, i.e., PRR, COMR, INT, AM and PSR, is 71.74 per cent. This also indicates that five tests, viz., proportional reasoning, combinatorial reasoning, general intelligence, achievement motive and propositional reasoning are predictors of the criterion variable in a sequence of decreasing contribution. Thus, hypothesis Ho4 : a is not accepted for three aspects of operational reasoning (PSR,

PRR, COMR), general intelligence and achievement motive but the same cannot be rejected for class-inclusion as it fails to contribute independently to the predicted variance.

Though class-inclusion correlates significantly with total concept attainment, it fails to contribute independently to the variance covered in the present study. This may be due to some commonality between this variable and the variables included in regression equation, i.e., PRR, COMR, INT, AM and PSR. A persual of Table 5.18 reveals that class-inclusion is significantly and positively related to proposition, proportion, combination, general intelligence and achievement motive. It might be possible that the factors in the class-inclusion which are common to that in PRR, COMR, INT, AM and PSR must have already been covered by the variance accounted for with the former variables and thus leading the contribution of class-inclusion to an insignificant level.

The regression equation to predict total concept attainment score in physics, when different aspects of operational reasoning along with general intelligence and achievement motive are used as predictor variables, on the basis of analysis presented in Table 5.20 may be written as follows :

$$Y' = 8.5982 + 1.2878\ \text{PRR} + 1.4062\ \text{COMR} + 0.2360\ \text{INT} + 0.1452\ \text{AM} + 0.3397\ \text{PSR} + 0.4433\ \text{CI}$$

where,

8.5982 is the intercept term.

This equation considers all the predictor variables. Class-inclusion did not contribute significantly towards prediction of variance, so the equation without consideration of this variable is given below. For this b-weights and intercept term are changed which are not shown in Table 5.20.

$$Y' = 9.1707 + 1.3206\ \text{PRR} + 1.4317\ \text{COMR} + 0.2423\ \text{INT} + 0.1505\ \text{AM} + 0.3516\ \text{PSR}$$

where,

9.1707 is the intercept term.

Nearly two third of the variance in total concept attainment scores is being explained by two subtests of TCP. The results indicate that certain reasoning abilities are necessary for successfully attaining physics concepts, especially proportional reasoning and combinatorial reasoning. Examining the scores of students on these subtests it may be said who will and who will not attain the concepts of physics successfully.

The investigator could not locate a single study which used logical thinking, general intelligence, achievement motive, or class-inclusion, propositional reasoning, proportional reasoning, combinatorial reasoning, general intelligence and achievement motive as predictor variables at a time. However, a large number of studies are available which used logical thinking in combination of other variables, or different sets of reasoning abilities as predictor variables for predicting science achievement/understanding of science concepts. Most of studies (Raven and Polanski, 1974 ; Raven et al., 1974 ; Howe and Early 1979 ; Glass, 1981 ; Chiappetta and Russell, 1982 ; Dettloff, 1983 ; Staver and Halsted, 1984 ; Hofstein and Mandler, 1985 ; Tobin, 1986) seem to support the findings of this study. However, among the studies reviewed, the researcher could not locate a study where logical thinking or combination of various reasoning abilities were reported to have covered above 50% of the variance in science achievement. Looking from this angle, it is clear that four subtests of TCP and their total (logical thinking) explain a very high portion of variance in total concept attainment scores in physics in the present study.

The results, here, are more promosing. The cause for such a high variance covered may be hidden in the fact that physics concept attainment here, as dependent variable, is more in congruity with operational reasoning because of the very nature of concept attainment tests and the nature of concepts taken.

The implications of these results for physics teachers may be drawn by considering the magnitude of variance accounted

for by TCP or its subtests, general intelligence and achievement motive. A large amount of variance in physics concept attainment scores is being explained by TCP or its four subtests, indicates that during the secondary and higher secondary school years, physics teachers may use the Tarkik Chintan Parikshan to identify students who probably will have difficulty in understanding concepts in physics. This determination may lead to the classification of pupils for advanced physics courses and/or segregation of students for other streams. Additionally, with this identification, teachers may design and select teaching strategies to facilitate the development of reasoning abilities and provide assistance to students before they become hopelessly lost in the course materials.

To conclude, it may be said that Tarkik Chintan Parikshan is very effective in predicting variance of measures of concept attainment in physics. In addition, it appears that four TCP subtests and their individual predicting power for a given criterion variable may provide considerable insight into the logical requirements of a given criterion variable. Furthermore, general intelligence and achievement motive also significantly predict total concept attainment scores in physics but are not so important as logical thinking, in general, or proportional reasoning and combinatorial reasoning, in particular. The knowledge about level of students on these predictor variables may help teachers, administrators to anticipate the emergence of future physicists which their schools can produce for the development of society if other environmental conditions remain conducive. This aspect is very important as our future school physics courses are to get more and more loaded with formal reasoning abilities due to rapid expansion of scientific knowledge.

5.2 4.3 Regression of Concept Attainment on Logical Thinking, General Intelligence and Achievement Motive : Results Related to Each Concept

Results related to the prediction of concept attainment in physics for each concept, viz., Force, Couple, TIR and Atom,

from predictor variables logical thinking, general intelligence and achievement motive have been presented in Table 5.21.

Table 5.21 shows that the multiple correlations of criterion (concept attainment scores in the concept Force, Couple, TIR and Atom) with logical thinking, general intelligence and achievement motive are 0.720, 0.711, 0.720 and 0.760, respectively. This implies that the total variance explained by these variables are 51.84%, 50.55%, 51.84% and 57.76% for concepts Force, Couple, TIR and Atom, respectively, Logical thinking alone accounts for 47.74% of the variance towards concept Force, 44.22% of the variance towards concept Couple, 48.30% of the variance towards concept TIR and 52.42% of the variance towards concept Atom. General intelligence also contributes significantly for the prediction of concept attainment scores in all the concepts. The variance covered by general intelligence is 2.95% ($p<0.01$), 5.06% ($p<0.01$), 3.11% ($p<0.01$) and 4.73% ($p<0.01$) for concepts Force, Couple, TIR and Atom, respectively. The variance explained by achievement motive is small, though significant for all concepts except TIR. Its contribution towards the concept Force is 1.15% ($p<0.01$), Couple is 1.27% ($p<0.01$), TIR is 0.43% ($p>0.05$) and Atom is 0 61% ($p<0.05$). Keeping in view above results, null hypotheses Ho3 : b, c, are not accepted as each of three predictors (LOTH, INT and AM) contribute significantly towards prediction of attainment scores in concepts Force, Couple and Atom. However, there is no evidence to reject hypothesis Ho3 : d for the contribution of variable achievement motive towards concept attainment in concept TIR. But the same hypothesis (Ho3 : d) is not accepted for the contribution of variance towards concept attainment in concept TIR by variable logical thinking and general intelligence as both cover significant amount of variance.

Though achievement motive correlates significantly with concept attainment scores in the concept TIR, it does not contribute significantly toward the variance covered for TIR.

The reason for such a result may be due to some commonality between achievement motive and variables considered earlier, i.e., logical thinking and general intelligence. The possibility is that the factors in achievement motive which are common to that in logical thinking and general intelligence and must have already been covered by the variance explained by with the former variables.

The specification equations to predict concept attainment scores from predictor variables logical thinking, general intelligence and achievement motive for all the four concepts, on the basis of Table 5.21 are as follows :

$$Y'_{Force}=1.2514+0.2495\ \text{LOTH}+0.0448\ \text{INT}+0.0416\ \text{AM}$$
$$Y'_{Couple}=0.9325+0.2462\ \text{LOTH}+0.0723\ \text{INT}+0.0504\ \text{AM}$$

$$Y'_{TIR}=2.6448+0.2620\ \text{LOTH}+0.0554\ \text{INT}+0.0232\ \text{AM}$$
$$Y'_{Atom}=1.1335+0.2727\ \text{LOTH}+0.0709\ \text{INT}+0.0334\ \text{AM}$$

Where 1.2514, 0.9325, 2.6448 and 1.1335 are intercept terms for concepts Force, Couple, TIR and Atom, respectively.

Since achievement motive did not contribute significantly toward prediction of variance in concept attainment for the concept TIR, the revised regression equation for concept TIR may be written as follows :

$$Y'_{TIR}=4.7873+0.2672\ \text{LOTH}+0.0623\ \text{INT}$$

where,

4.7873 is the intercept term.

This equation is without consideration of achievement motive as independent variable. That is why b-weights and intercept terms got changed which are not shown in Table 5.21.

An overview of results presented in Table 5.21 makes it clear that logical thinking is the strongest predictor of concept attainment scores, separately, in all the four concepts studied

in this investigation. The fact that logical thinking explains for more variance in concept attainment scores than general intelligence and achievement motive for all the concepts, strengthens the importance of logical thinking in predicting attainment of individual physics concepts and substantiates the results of section 5.2.4.1. General intelligence also seems to be an important variable as it covers significant variance for all the concepts, separately. Achievement motive does not seem to be as important as logical thinking and general intelligence because it explains only a small, though significant, variance in concept attainment scores for all the concepts except TIR where it does not even contribute significantly.

5.2.4.4 Regression of Concept Attainment on Various Aspects of Operational Reasoning, General Intelligence and Achievement Motive : Results Related to Each Concept

Specification equations for each concept were arrived at by taking general intelligence, achievement motive and various aspects of operational reasoning as predictor variables. Results related to prediction of concept attainment scores for each concept in physics through these predictor variables have been presented in Table 5.22.

A persual of Table 5.22 shows that the total accountable variance for predictor variables, viz., general intelligence, achievement motive and various aspects of operational reasoning, are 54.32%, 53.00%, 54.02% and 58.83% for the concepts Force, Couple, TIR and Atom, respectively. Out of four operational reasoning, proportional reasoning and combinatorial reasoning predict major and significant portion of variance consistently for all the eoncepts. Proportional reasoning explains 9.42% ($F=42.60$, $p<0.01$), 37.58% ($F=143.27$, $p<0.01$), 10.00% ($F=46.98$, $p<0.01$), and 45.97% ($F=202.48$, $p<0.01$) of variance towards concepts Force, Couple, TIR and Atom, respectively. The variance accounted for by combinatorial reasoning towards concepts Force, Couple, TIR and Atom are 38.19%, 4.22%, 39.56%, respec-

tively. Propositional reasoning and class-inclusion contribute a small amount of variance, though significant, towards prediction of concept attainment scores in physics for some concepts but not for all. Propositional reasoning contributes significantly only for the concept Atom (0.46%, $F=2.60$, $p<0.05$) whereas class-inclusion contributes significant amount of variance (2.02%, $F=10.18$, $p<0.01$) for the concept Force only.

General intelligence explains significant amount of variance towards prediction of concept attainment scores in all the concepts. It explains 3.66% ($F=17.70$, $p<0.01$) of variance for the concept Force, 9.76% ($F=43.91$, $p<0.01$) of variance for the concept Couple, 3.73% ($F=18.84$, $p<0.01$) of variance for the concept TIR and 9.38% ($F=49.82$, $p<0.01$) of variance for the concept Atom. Achievement motive does not cover significant amount of variance towards prediction of the concept TIR, but covers significant amount of variance for prediction of attaiment scores in concepts Force (0.88%, $F=4.49$, $p<0.01$), Couple (1.16%, $F=5.74$, $p<0.01$) and Atom (0.46%, $F=2.57$, $p<0.05$).

In view of the results in Table 5.22, Ho4 : b, c, d, e is not to be accepted for all the predictor variables. Hypothesis Ho4 : b is not tenable for variables class-inclusion, proportional reasoning, combinatorial reasoning, general intelligence and achievement motive. However, there is no evidence to reject the same hypothesis (Ho4 : b) for the contribution of propositional reasoning towards prediction of concept attainment scores in concept Force.

Results related to prediction of concept attainment scores in concept Couple suggest that hypothesis Ho4 : C is not rejected for variables class-inclusion and propositional reasoning. However, the same (Ho4 : C) is not accepted for contribution of variance towards prediction of concept attainment scores in concept Couple by variables proportional reasoning, combinatorial reasoning, general intelligence and achievement motive.

Keeping in view the results related to the prediction of attainment scores in concept Total Internal Reflection hypothesis Ho4 : d is not accepted for variables proportional reasoning, combinatorial reasoning and general intelligence. However, the same is not rejected for variables class-inclusion, propositional reasoning and achievement motive.

Similarly for prediction of concept attainment scores in concept Atom, hypothesis Ho4 : e is not accepted for variables propositional reasoning, proportional reasoning, combinatorial reasoning, general intelligence and achievement motive. However, results in Table 5.22 do not provide evidence to reject Ho4 : e for variable class-inclusion.

Specification equations for prediction of concept attainment scores in each concept are given below :

$$Y'_{Force}=1.3979+0.3647\ \mathrm{COMR}+0.2292\ \mathrm{PRR}+0.0405\ \mathrm{INT}+0.5188\ \mathrm{CI}+0.0369\ \mathrm{AM}+0.0434\ \mathrm{PSR}$$

$$Y'_{Couple}=2.1740+0.3525\ \mathrm{PRR}+0.0732\ \mathrm{INT}+0.3739\ \mathrm{COMR}+0.0523\ \mathrm{AM}-0.2372\ \mathrm{CI}+0.0663\ \mathrm{PSR}$$

$$Y'_{TIR}=3.7013+0.4204\ \mathrm{COMR}+0.2989\ \mathrm{PRR}+0.0554\ \mathrm{INT}+0.1090\ \mathrm{PSR}+0.0250\ \mathrm{AM}-0.0874\ \mathrm{CI}$$

$$Y'_{Atom}=1\ 4226+0.4096\ \mathrm{PRR}+0.0704\ \mathrm{INT}+0.2412\ \mathrm{COMR}+0.0301\ \mathrm{AM}+0.1124\ \mathrm{PSR}+0.2154\ \mathrm{CI}$$

These equations consider all the predictor variables. Some of the variables did not contribute significantly towards prediction of variance for all the concepts. Equations without consideration of these variables are given below. For this b-weights and intercept terms are changed which are not shown in Table 5.22. The variables which did not contribute significantly differ from concept to concept.

$$Y'_{Force}=1.3945+0.3659\ COMR+0.2373\ PRR+ 0.0421\ INT+0.5254\ CI+0\ 0367\ AM$$

$$Y'_{Couple}=1.8748+0.3468\ PRR+0.0722\ INT+ 0.3625\ COMR+0.0493\ AM$$

$$Y'_{TIR}=5.7871+0.4215\ COMR+0.3243\ PRR+ 0.0655\ INT$$

$$Y'_{Atom}=1.7008+0.4256\ PRR+0.0735\ INT+ 0.2536\ COMR+0.0327\ AM+0.1182\ PSR$$

The four subtests of Tarkik Chintan Parikshan (TCP) cover a sizeable portion of variance of physics concept attainment for all the concepts. Out of these four subtests proportional reasoning and combinatorial reasoning predict major portion of variance consistently for all the concepts. Whereas propositional reasoning and class-inclusion contribute significantly but small amount of variance towards prediction of concept attainment scores in physics for some of the concept. Class-inclusion, propositional reasoning and achievement motive correlate significantly with concept attainment scores in all the four physics concepts but fail to make significant contribution towards prediction of variance in some of the concepts. This may be due to some commonality of variance of these variables with those making significant contribution. All these indicate that proportional reasoning, combinatorial reasoning and general intelligence are very important variables for predicting performance in individual physics concepts. Achievement motive, class-inclusion and propositional reasoning are important variables only to predict performance in some of the physics concepts taken in this investigation.

These findings have considerable implications for science education. It means that operative structures defined by Jean Piaget and used on the TCP can provide the basis for determining if students will have problems with certain types of physics concepts. This capability of prediction is indicative of the power of these operative structures for diagnosing specific learning difficulties. After diagnosing the specific

operative structures that are responsible for learning problems, the teacher may formulate remedial activities that may assist in the learning of concepts. One of the strongest schemes for analyzing the content structure uses the operative structure defined by Jean Piaget. It may be suggested that the reasoning requirements for TCP might be considered efficient model for designing curriculum materials and diagnosing and prescribing for physics concept learning difficulties.

5.2.5 Interaction of Achievement Motive and Cognitive Development on Concept Attainment in Physics

After exploring the relationship between operational reasoning and concept attainment in physics along with analysing the differences in concept attainment of concrete and formal thinkers, a need was felt to find out the interaction effect of the cognitive developmental level (concrete/formal) and achievement motive on physics concept attainment. For this, two-way analysis of covariance with unequal cell frequencies was carried out to see the level × level interaction for the total concept attainment scores in physics. Additionally, analyses were also carried out for each concept, separately. In all these analyses, pretest concept attainment scores either total or in each concept, as the case may be, were used as covariates. Such a technique was adopted to bring forth a summary of mass statistical data in which the logical content of the whole can be readily appreciated. It is convenient in facilitating and reducing to a common form all the tests of significance one wants to apply and also enables to study the interaction effect of two or more variables at a time.

The research being in education and the experimental control being out of reach, no treatment of the cognitive developmental level and achievement motive could be given, the choice automatically fell upon seeing diffrent treatment effects through the segregation of students into different levels. Students were categorized as being concrete or formal thinkers on the basis of their scores on TCP. Raw scores related to AMI were labelled as high, average and low on the basis of

P_{75} and P_{25} cut-points. Thus, a 3×2 factorial design was employed for the ANCOVA in which two factors, achievement motive and stages of cognitive development were studied with three and two levels, respectively, when initial differences had been adjusted with respect to initial knowledge in physics concepts. The number of observations in six cells for different levels being unequal, the method of analysis of covariance with unbalanced data was employed (Winer, 1971).

The concept attainment scores of students were put into different sub-classes or cells designated as high, average or low for achievement motive and concrete, formal for cognitive development. Table 5.23 shows number of observations in all six cells for different combinations of achievement motive and cognitive developmental level.

Table 5.23

Number of Observations per cell for Different Combinations of Achievement Motive and Cognitive Developmental Levels

		Cognitive Development		Total
		Concrete	Formal	
	High	38	23	61
Achievement	Average	81	39	120
Motive	Low	52	7	59
	Total	171	69	240

To measure the interaction effect of achievement motive and cognitive development on physics concept attainment scores, means of each cell, and total of means for each row and column were computed for the covariate (pretest concept attainment scores, X) and the dependent variable (post-test concept attainment scores, Y). These are presented in Table 5.24.

Table 5.24

Means of Pretest and Post-test Concept Attainment Scores in Different Sub-classes, and Total of means for each row and column

		Cognitive Development				Total of means	
		Concrete		Formal			
		Pre-test (X)	Post-test (Y)	Pre-test (X)	Post-test (Y)	Pre-test (X)	Post-test (Y)
Achievement Motive	High	44.18	55.66	52.30	70.00	96.48	125.66
	Average	38.43	49.11	49.21	67.72	87.64	116.83
	Low	38.46	45.08	46.43	64.86	84.89	109.94
	Total of means	121.07	149.85	147.94	202.58	269.01	352.43

Sum of squares of total concept attainment scores for achievement motive, cognitive developmental level and their interaction along with residual were computed following the details given by Winter (1971, pp. 792-796). Final results along with mean sum of squares, F-ratios and their significance have been presented in Table 5.25.

Table 5.25

Summary of ANCOVA for estimating Interaction of Achievement Motive and Cognitive Development on Total Concept Attainment in Physics

Source of Variation	SS	df	MSS	F	p
Achievement motive	236.52	2	118.26	4.19	<0.05
Cognitive development	3093.82	1	3093.82	109.63	<0.01
Interaction	174.94	2	87.47	3.10	<0.05
Residual	6574.78	233	28.22		

The results in Table 5.25 show that interaction of achievement motive and cognitive developmental level on concept attainment in physics are significant. That is, physics concept attainment scores are affected by combined effect of achievement motive and cognitive developmental level. Thus, hypothesis Ho5 : a is not accepted.

It can be inferred that high, average or low achievement motive levels when interact with concrete or formal XI-graders, it results in differentiated concept attainment in physics. It is not possible to examine precisely, which combination of levels actually accelerates or retards the total concept attainment in physics of XI-graders, mostly through present type of data, though it can only be inferred. Purpose of this analysis was only to see the presence or absence of interactional effect. Having found the interactional effect, fresh experiments need to be performed with controlled groups in each cell, and only then exact combination of level × level affecting physics concept attainment mostly, can be sorted out by testing the significance of the difference between their means.

In addition to significant interaction effect, F-value for main effect of cognitive development yielded highly significant result ($F=109.63$, $p<0.01$). This gives added confidence in interpreting the mean concept attainment of concrete and formal thinkers averaged over three levels of achievement motive, when initial differences had been adjusted with respect to initial knowledge of physics concepts. This means that total concept attainment scores in physics of XI-grade science students are highly dependent on the differences in their cognitive development.

Further persual of Table 5.25 shows that F-value for the main effect of achievement motive is significant for total concept attainment ($F=4.19$, $p<0.05$). In the present case this F-value for the main effect of achievement motive corresponds to a comparison between mean concept attainment scores of high, average and low achievement motive groups

over two cognitive developmental levels. This means that total concept attainment scores in physics of XI-grade science students are significantly affected by their differences in achievement motive, when initial differences had been adjusted with respect to initial knowledge of physics concepts.

No other study has yet come in the knowledge of the investigator relating to the interaction of achievement motive and cognitive development on physics concept attainment or achievement in physics. However, Staver and Halsted (1982) found that interaction of Piagetian reasoning, model usage, and sex type accounted for a significant portion of variance in total scores, and in the memory and application sections of the achievement test. Abraham and Renner (1986) also reported the presence of interaction effect between class level and developmental level on concept achievement in chemistry.

The interaction effect found in this section does not allow the investigator to generalize that cognitive development and achievement motive in combination will affect the concept attainment in physics all the time and for all the samples of XI-graders as this has the limitation of generalizability due to the ex-post facto nature of the research with level × level interaction instead of treatment × treatment interaction. However, the situation may become more vivid if the interaction effect for concept attainment in each concept is computed and results analyzed. Consistent interaction effect for all or most of the concepts, if present, may bring the result in this section to a generalizable standard for the present study.

5.2.5.1 Interaction of Achievement Motive and Cognitive Development on Concept Attainment in Physics : Results Related to Each Concept

After analysing the interaction effect of achievement motive and cognitive development on total concept attainment scores in physics, a need was felt to find out the interaction effect for each concept separately to infer the interaction effect present

for total concept attainment scores with more confidence. The concept attainment scores of students were put into different

Table 5.26

Means of Pretest and Posttest Concept Attainment Scores in Different Sub-classes and Total of Means for each row and each Column for each Concept Separately

			Cognitive Development				Total of means	
			Concrete		Formal			
			Pre-test (X)	Post-test (Y)	Pre-test (X)	Post-test (Y)	Pre-test (X)	Post-test (Y)
	FORCE	High	11.13	13.29	11.78	15.83	22.91	29.12
		Average	9.01	11.73	11.38	16.10	20.39	27.83
		Low	8.62	10.62	10.14	14.86	18.76	25.48
		Total	28.76	35.64	33.30	46.79	62.06	82.43
ACHIEVEMENT MOTIVE	COUPLE	High	11.42	15.45	14.57	19.30	25.99	34.75
		Average	10.85	13.46	12.67	18.23	23.52	31.69
		Low	10.69	12.71	10.57	17.43	21.26	30.14
		Total	32.96	41.62	37.81	54.96	70.77	96 58
	TIR	High	9.74	12.92	10.87	17.30	20.61	30.22
		Average	8.04	11.69	11.26	16.21	19.30	27.90
		Low	9.00	10.60	11.71	16.57	20.71	27.17
		Total	26.78	35.21	33.84	50.08	60.62	85.29
	ATOM	High	11.89	14.00	15 09	17.57	26.98	31.57
		Average	10.57	12.33	13.90	17.18	24.47	29.51
		Low	10.15	11.19	14.00	16.00	24.15	27.19
		Total	32.61	37.52	42.99	50.75	75.60	88.27

cells designated as high, average and low for achievement motive and concrete, formal for cognitive developmental level for each concept, separately. The number of observations in each cell are the same as shown in Table 5.23 because groups were segregated on the basis of achievement motive scores and scores on TCP. Mean of each cell and total of means for each row and each column for the covariate (pretest concept attain-

Table 5.27

Summary of ANCOVA for Estimating Interactions of Achievement Motive and Cognitive Development on Concept Attainment in each Concept

	Source of Variation	SS	df	MSS	F	P
FORCE	Achievement motive	14.56	2	7.28	1.53	>0.05
	Cognitive development	267.94	1	267.94	56.41	<0.01
	Interaction	8.84	2	4.44	0.93	>0.05
	Residual	1107.65	233	4.75		
COUPLE	Achievement Motive	27.28	2	13.64	1.97	>0.05
	Cognitive development	414.58	1	414.58	59.91	<0.01
	Interaction	37.09	2	18.55	2.68	>0.05
	Residual	1612.33	233	6.92		
TIR	Achievement motive	53.50	2	26.75	5.38	<0.01
	Cognitive development	475.29	1	475.29	95.63	<0.01
	Interaction	15.52	2	7.76	1.56	>0.05
	Residual	1158.48	233	4.97		
ATOM	Achievement motive	42.60	2	21.30	5.31	<0.01
	Cognitive development	146.97	1	146.97	36.65	<0.01
	Interaction	8.41	2	4.21	1.05	>0.05
	Residual	934.96	233	4.01		

ment score, X) and the dependent variable (posttest concept attainment scores, Y) have been shown in Table 5.26 for each concept, separately.

Sum of squares for achievement motive, cognitive developmental level, interaction and residual were calculated following Winer (1971) and the final results along with mean sum of squares, F-ratios and their significance have been presented in Table 5.27.

From the results in Table 5.27, it is apparent that F-ratios for interaction show no significant effect anywhere for any concept. Hence, concept attainment in individual concepts for XI-grade science students are not affected by the interaction of achievement motive and cognitive development. That is, physics concept attainment of XI-graders are not dependent on the combined effect of achievement motive and cognitive development. No combination of levels of achievement motive and cognitive development does significantly boost up or reduce the concept attainment scores of XI-graders for any of the concepts when initial knowledge on these concepts had been held constant. Thus hypotheses Ho5 : b, c, d, e are not rejected.

In the last section, significant interaction of achievement motive and cognitive development on total concept attainment scores in physics was found. But that result cannot be generalized as the analysis of data for each concept separately revealed the absence of interaction effect as none of the F-ratios for interaction came out to be significant.

In addition to non-significant interaction effect, F-ratios for main effect of cognitive development showed highly significant results ($F=56.41$ for Force, $F=59.91$ for Couple, $F=95.63$ for TIR, $F=36.65$ for Atom, for all F-ratios $p<0.01$). This gives added confidence in interpreting the mean concept attainment of concrete and formal thinkers averaged over three levels of achievement motive, when initial differences had been adjusted with respect to initial knowledge

of physics concepts, for each concept separately. This means that concept attainment scores in individual physics concepts of XI-grade science students are highly dependent on the differences in their cognitive developmental level. Formal thinkers, capable of hypothetico-deductive reasoning, perform significantly better than concrete thinkers whose reasoning is limited to concrete and tangible objects.

Further, Table 5.27 shows that F-value for the main effect of achievement motive is significant for two concepts, TIR ($F=5.38$, $p<0.01$) and Atom ($F=5.31$, $p<0.01$), only. For concepts Force and Couple it shows non-significant F-values. In the present case, this F-value for the main effect of achievement motive corresponds to a comparison between mean concept attainment scores of high, average and low achievement motive groups averaged over two cognitive developmental levels. This result shows that concept attainment scores on TIR and Atom are dependent on the differences in achievement motive of students when initial differences had been adjusted with respect to prior knowledge of concepts TIR and Atom, respectively. However, concept attainment scores on Force and Couple are not affected by achievement motive when initial differences had been adjusted with respect to prior knowledge on concepts Force and Couple, respectively. A possible explanation for this sort of result may be given by looking into the characteristics included to measure achievement motive of students and concepts selected for this study. Concepts TIR and Atom are covered in XII-grade whereas Force and Couple are covered during XI-grade. From the viewpoint of examination, concepts Force and Couple were of immediate gain to students whereas TIR and Atom were not of such gain to these XI-grade students. Students high in achievement motive have high aspiration level, upward mobility and may take risk more than those low in motive to achieve. These characteristics might lead to better concept attainment scores in concepts not of immediate gain for students high in achievement motive.

In the absence of significant interaction for all the concepts

studied, it is not possible to find out any combination of levels of achievement motive and cognitive development whose deliberate enhancement through school programmes will automatically help in increasing the attainment of individual physics concepts of XI-grade science students. However, this inference is tentative and needs further researches to get supportive base. Presence of significant interaction effect would have helped the classroom teachers and schools to include such techniques and aspects in their lessons, co-curricular programmes and indirect influences on students, which might help in developing required achievement motive along with the enhancement of logical thinking ability in general. These measures would have ultimately supplemented the attainment of physics concepts apart from the stereotyped classroom teaching.

6

Summary, Conclusions and Suggestions for Further Research

6.1 Summary

Majority of science concepts taught at higher secondary level are abstract and require formal thought for their understanding. It is reasonable to believe that formal-operational students, who are capable of hypothetical thought, will learn physics concepts better than concrete-operational students who reason from concrete objects and work with logical operations that refer to empirical reality. A large number of studies have reported that formal thinkers outperform concrete thinkers in science achievement and understanding of science concepts which are related to students' operational reasoning ability. As a consequence of these researches, several writers have emphasized the need to modify objectives, content, and teaching methods according to the level of cognitive development of learners. Some writers have also urged that the development of formal-operational reasoning should be a major priority in science education.

Cognitive development is thought to be a guiding factor for science achievement and attainment of science concepts. Some studies revealed insignificant relationship between formal-operational reasoning and science achievement and found students of differing cognitive levels to achieve similarly. Inconsistency in findings related to operational reasoning

ability and science achievement, and effect of cognitive developmental level on science achievement creates the need of further investigation in this domain.

Relationship between operational reasoning ability and concept attainment did not cover the whole problem area. In addition to significant relationship, if obtained, between operational reasoning ability and concept attainment in physics, a question arose whether the relationship was due to confounding effect of other variables or not ? Although cognitive development was supposed to be an important factor for concept attainment, studies suggested that other variables also affect achievement and understanding of science concepts, viz., teaching methods, achievement motive, previous knowledge, general intelligence, etc. It seemed reasonable to see the relationship between operational reasoning and concept attainment in physics and effect of stages of cognitive development on concept attainment in physics after partialling out the effect of some variables. Additionally, a question before the investigator was to see whether the combined effect of logical thinking/operational reasoning ability, general intelligence and achievement motive could provide higher correlations with performance on concept attainment tests in physics than either measure alone along with the relative importance of these measures for concept attainment in physics.

Therefore, the present investigation was concerned with the manyfold problem such as :

(i) Distribution of Piagetian developmental levels,
(ii) Relationship between operational reasoning and concept attainment in physics,
(iii) Effect of stages of cognitive development on concept attainment in physics,
(iv) Determination of predictive validity of operational reasoning, general intelligence and achievement motive for concept attainment in physics,
(v) Measurement of interaction of achievement motive and cognitive development, and

(vi) Sex difference in operational reasoning.

Logical thinking and different aspects of operational reasoning were measured by Tarkik Chintan Parikshan (TCP) a Hindi adaptation of Longeot's test of cognitive development (1962, 1965). General intelligence and achievement motive were measured by employing Joshi's (1969) Group Test of General Mental Ability and Achievement Motive Inventory (Gandhi and Srivastava, 1982), respectively. For measuring concept attainment in physics, four concept attainment tests, on Couple and TIR (Bhattacharya and Pandey, 1981) and Force and Atom (Bhattacharya and Pandey, 1985), were used.

The present investigation, an ex-post facto research, was conducted on the population of higher secondary science students of Varanasi City. To draw out the sample, incidental and purposive sampling technique was employed. The sample consisted of 240 (147 boys and 93 girls) XI-grade science students selected from four intermediate colleges of Varanasi city. These 240 students were those who were present during all the activities, viz., administration of tests and teaching. Four concepts of physics, viz., Force, Couple, Total Internal Reflection and Atom were taught following the same teaching format (Cantu and Herron, 1978) by the investigator to provide control for teaching method and teachers' effect.

Partial correlations were computed to find out the relationship between operational reasoning and concept attainment in physics with the effect of general intelligence and achievement motive partialled out. One-way analysis of covariance was used to find out the effect of stages of cognitive development on concept attainment in physics with the effect of previous knowledge in physics, general intelligence and achievement motive held constant. Step-wise multiple regression was carried out to find out the joint and relative contribution of different variables towards concept attainment in physics. Analysis of covariance with 3×2 design was employed for measuring interaction of achievement motive and stages of cognitive development on concept attainment in physics by

using the method of unweighted mean (Winer, 1971) for unequal observations per cell. In the allied studies, 't' test and percentages were worked out to find out the sex difference in operational reasoning and logical thinking, and distribution of cognitive levels.

6.2 Conclusions

The conclusions obtained from the results reported in Chapter III and V are summarized below :

1. Majority of XI-grade science students (71%) are functioning at the concrete-operational level. Only 29% students show formal-operational thinking.

2. (a) Various aspects of operational reasoning, viz., class-inclusion, propositional reasoning, proportional reasoning, combinatorial reasoning, and their total (logical thinking) are highly related ($r=0.430$ to 0.799) with total concept attainment in physics of XI-grade students. Significant correlations, after holding constant the effects of general intelligence and achievement motive, ($r=0.229$ to 0.621) show that logical thinking and different aspects of operational reasoning strongly influence concept attainment in physics.

   (b) Second order partial correlation coefficients of concept attainment in concepts Force, Couple, Total Internal Reflection and Atom with logical thinking, propositional reasoning, proportional reasoning and combinatorial reasoning were found to be positive and significant ($r=0.149$ to 0.513). Except concept attainment in concept Couple, class-inclusion revealed significant correlation with concept attainment in Force, Total Internal Reflection and Atom. Consistently high correlations of proportional reasoning and combinatorial reasoning, in particular, and logical thinking, in general, with all the physics concepts, selected for

this study, suggest that they are very important for better performance in physics.

3. The formal-operational XI-grade science students outperform their concrete-operational counterparts on total concept attainment in physics as well as on concept attainment in individual concepts, viz., Force, Couple, Total Internal Reflection and Atom even after both groups had been made equal with respect to previous knowledge in physics, general intelligence and achievement motive. Formal-operational students seemed to possess greater capacity to attain concepts than concrete-operational students.

4. (a) The multiple correlation of total concept attainment in physics with logical thinking, general intelligence and achievement motive was found to be 0.836. This means that 69.89% of the variance in total concept attainment in Physics has been covered by these three predictor variables. Logical thinking (63.84%), general intelligence (5.05%) and achievement motive (1.00%), all make significant contributions towards prediction of total concept attainment in Physics.

   (b) The results obtained by the process of multiple regression analysis of concept attainment in each concept on logical thinking, general intelligence and achievement motive indicated that attainment in concepts Force, Couple and Atom was predicted significantly by all three variables. For concept Total Internal Reflection, logical thinking and general intelligence were the best predictors. The total variance explained by the combination of best predictors was 51.84%, 50.55%, 51.41% and 57.76% for concepts Force, Couple, Total Internal Reflection and Atom, respectively. Among these variables, logical thinking emerged as the strongest predictor of concept attainment in all the concepts.

5. (a) Multiple correlation of total concept attainment in Physics with general intelligence, achievement motive and various aspects of operational reasoning was found to be 0.847 which indicated that 71.74% of the variance in total concept attainment scores in Physics was being explained by these six predictor variable. Out of these six predictors, proportional reasoning (52.27%), combinatorial reasoning (12.05%), general intelligence (6.07%), achievement motive (1.01%) and propositional reasoning (0.34%) make significant contributions. Class-inclusion fails to make any significant contribution.

   (b) The multiple regression analysis of concept attainment in each concept on general intelligence, achievement motive and various aspects of operational reasoning revealed that combinatorial reasoning, proportional reasoning, general intelligence, class-inclusion and achievement motive were the best predictors for concept Force ; proportional reasoning, general intelligence, combinatorial reasoning and achievement motive were the best predictors for concept Couple ; combinatorial reasoning, proportional reasoning and general intelligence were the best predictors for concept Total Internal Reflection ; whereas proportional reasoning, general intelligence, combinatorial reasoning, achievement motive and propositional reasoning were the best predictors for the concept Atom. The total variance explained by the combination of these best predictors was 54.17%, 52.71%, 53.29% and 58.68% for concept Force, Couple, Total Internal Reflection and Atom, respectively.

6. (a) (i) Significant interaction effect of achievement motive and stages of cognitive development on total concept attainment in Physics was

found ($F=3.10$, $p<0.05$) after holding the effect of previous knowledge in physics constant.

(ii) Main effect of achievement motive was significant for total concept attainment in physics after holding the effect of previous knowledge in physics constant.

(iii) Total concept attainment in physics is greatly affected by cognitive developmental level as significant and large F-ratio is obtained for the main effect of developmental level after holding the effect of previous knowledge in physics constant.

(b) (i) Concept attainment in individual physics concepts, viz., Force, Couple, Total Internal Reflection and Atom, were not found to be significantly affected by the interaction of achievement motive and stages of cognitive development when previous knowledge in individual physics concepts is held constant.

(ii) Main effects of achievement motive was found to affect the attainment of only two concepts, viz., Total Internal Reflection and Atom after holding the effect of previous knowledge in individual physics concepts constant.

(iii) Main effects of cognitive developmental level was found to highly affect the concept attainment in individual physics concepts, viz., Force, Couple, Total Internal Reflection and Atom, even after holding the effect of previous knowledge in individual physics concepts constant.

7. It was found that Tarkik Chintan Parikshan is a valid and reliable instrument to assess Piagetian developmental level of higher secondary students.

8. It was found that male and female XI-grade science students do not differ in any of the operational reasoning, viz., class-inclusion, proposition, proportion and combination and their total (logical thinking).

6.3. Implications for Classroom Teaching

Piaget has not concerned himself primarily with the implications of his theory for classroom teaching. Therefore, the researcher has only Piaget's theory of cognitive development and the findings of this study from which to draw implications for classroom teaching. The implications are purely speculative due to restrictive nature of this study.

The results show that only 29% of the XI-grade science students are capable of formal thinking. So, for effective learning methods of teaching, curriculum should be planned in such a way that the structure of content is matched with the level of intellectual development of students. However, erosion of academic standards to accommodate large proportion of concrete operationals should not be allowed. Traditionally, curricula have been constructed by adults using different philosophical bases for their organization. But the main concern of the approach to curriculum should be the development at cognitive competencies. In such a design, learning of abilities like observing, measuring, hypothesizing, predicting, and so on is the basic concern. In this type of curriculum, subject matter becomes the vehicle for developing children's strategies of thought. In addition to this, science teachers should be trained, especially for applying the developmental approach to classroom situations. The teacher should be able to assess the developmental level of his student and then expose him to problem situations that are slightly beyond this level. These situations cause puzzlement or query by the student. In order to resolve the pending situation, the student must change his way of thinking by equilibration. Learning through equilibration requires activity by the student. For this the teacher should use (i) methods that actively involve students (such as laboratory hands on activities, field trips, etc.) and (ii) counter-

found ($F=3.10$, $p<0.05$) after holding the effect of previous knowledge in physics constant.

(ii) Main effect of achievement motive was significant for total concept attainment in physics after holding the effect of previous knowledge in physics constant.

(iii) Total concept attainment in physics is greatly affected by cognitive developmental level as significant and large F-ratio is obtained for the main effect of developmental level after holding the effect of previous knowledge in physics constant.

(b) (i) Concept attainment in individual physics concepts, viz., Force, Couple, Total Internal Reflection and Atom, were not found to be significantly affected by the interaction of achievement motive and stages of cognitive development when previous knowledge in individual physics concepts is held constant.

(ii) Main effects of achievement motive was found to affect the attainment of only two concepts, viz., Total Internal Reflection and Atom after holding the effect of previous knowledge in individual physics concepts constant.

(iii) Main effects of cognitive developmental level was found to highly affect the concept attainment in individual physics concepts, viz., Force, Couple, Total Internal Reflection and Atom, even after holding the effect of previous knowledge in individual physics concepts constant.

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intuitive problems (to involve students in problem-solving situations). He should carefully select and use thoughtful questions as questioning is one of the most common ways teachers try to engage the learner and establish disequilibrium. The teacher should structure learning environment so as to enable the student to discover through his own mental actions concepts and principles. In addition to setting up the environment the teacher should act as a facilitator in helping students make discoveries.

Results of this study show that factual and conceptual knowledge, which the students have acquired, is associated with their operational reasoning ability and formal-operational students outperform concrete-operational students. It seems that physics teaching at higher secondary level has been least concerned about the intellectual development of students. It seems to assume that when students accumulated information about mechanics, heat, sound, light, magnetism, electricity and modern physics, intelluctual development occurred. But this assumption seems to be unjustified as majority of higher secondary students are still functioning at the concrete-operational level. In such a situation, redesigning of physics curricula to minimize the need for formal thought, may appear to be an obvious solution. But, this reasoning is frightening. Instead of trying to eliminate the need for formal thought, curricula should be so designed that students have many opportunities to apply formal-operational reasoning. Instruction should allow students the opportunities to generate and test hypotheses within the context of the discipline. Simply providing students with ready-made hypotheses and cookbook recipes for their verification is not sufficient. The opportunities to apply formal thought should be interpersed with a lot of concrete experiences of the type which support the activities that require formal thought. When no direct example of the concept is available which can be shown to students or the examples which can be shown to reveal the characteristics of the concepts, efforts should be made to develop and use effecctively psuedo-examples which might help student's learning.

While sequencing concepts in curricula, or deciding on the

methods of teaching or providing experiences to students to develop operational reasoning, there is no need to make different amount of specified effort on the basis of sex as this study gives no evidence regarding the superiority of boys over girls.

6.4. Suggestions for Further Research

Based on the findings and discussions in this study, it is suggested that further researches be carried out using variations of this study. It is suggested that following problems may be undertaken :

1. Similar studies may be undertaken in other subject areas such as, chemistry, biology, mathematics, etc.
2. A study may be undertaken to develop instructional strategy for the enhancement of cognitive developmental level and concept attainment in physics.
3. Studies may be undertaken to develop instructional strategy for teaching formal concepts in physics through concrete instructional strategy.
4. Studies may be carried out to analyse and find out the reasoning requirements of various concepts in physics.

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APPENDIX—I

तार्किक चिन्तन परीक्षण*

(F. O. L. P., F. O. P., F. C. O.)

BY :

N. N. PANDEY

S. B. BHATTACHARYA

(कृपया इस परीक्षण-पुस्तिका में किसी भी तरह का निशान मत लगाइए)

Adapted from Dr. F. Longeot's Test (in French)

भाग I

इस परीक्षण पुस्तिका के पहले भाग में 5 प्रश्न हैं। प्रत्येक प्रश्न में दो कथन दिये गये हैं। इन कथनों के आधार पर तीन निष्कर्ष दिये गये हैं। लेकिन इन तीन निष्कर्षों में केवल एक सही है। **आपको यह पता करना है कि इन तीन निष्कर्षों में कौन सही है।**

उत्तर-पत्र में सही निष्कर्ष के नीचे वाले चौकोर खाने (□) में गुणा का निशान (×) लगाना है।

अब, आप प्रत्येक प्रश्न को पढ़िये तथा सही उत्तर को उत्तर-पत्र पर अंकित कीजिए। **पहले पाँच प्रश्नों तक केवल एक ही उत्तर सही है।**

1. **कथन** :

—स्तनधारी रीढ़ की हड्डी वाले होते हैं।

—रीढ़ की हड्डी वाले जन्तु होते हैं।

निष्कर्ष :

(अ) स्तनधारी जन्तु होते हैं।

(ब) स्तनधारी जन्तु नहीं होते हैं।

(स) इसे जाना नहीं जा सकता है।

2. **कथन** :

—राकेश किशोर से अधिक फुर्तीला है।

—किशोर मोहन से अधिक फुर्तीला है।

APPENDIX—I

तार्किक चिन्तन परीक्षण*

(F. O. L. P., F. O. P., F. C. O.)

BY :

N. N. PANDEY

S. B. BHATTACHARYA

(कृपया इस परीक्षण-पुस्तिका में किसी भी तरह का निशान मत लगाइए)

**Adapted from Dr. F. Longeot's Test (in French)*

भाग I

इस परीक्षण पुस्तिका के पहले भाग में 5 प्रश्न हैं। प्रत्येक प्रश्न में दो कथन दिये गये हैं। इन कथनों के आधार पर तीन निष्कर्ष दिये गये हैं। लेकिन इन तीन निष्कर्षों में केवल एक सही है। **आपको यह पता करना है कि इन तीन निष्कर्षों में कौन सही है।**

उत्तर-पत्र में सही निष्कर्ष के नीचे वाले चौकोर खाने (□) में गुणा का निशान (×) लगाना है।

अब, आप प्रत्येक प्रश्न को पढ़िये तथा सही उत्तर को उत्तर-पत्र पर अंकित कीजिए। **पहले पाँच प्रश्नों तक केवल एक ही उत्तर सही है।**

1. **कथन :**

—स्तनधारी रीढ़ की हड्डी वाले होते हैं।

—रीढ़ की हड्डी वाले जन्तु होते हैं।

निष्कर्ष :

(अ) स्तनधारी जन्तु होते हैं।

(ब) स्तनधारी जन्तु नहीं होते हैं।

(स) इसे जाना नहीं जा सकता है।

2. **कथन :**

—राजेश किशोर से अधिक फुरतीला है।

—किशोर मोहन से अधिक फुरतीला है।

निष्कर्ष :

(अ) तीनों बच्चों में किशोर सबसे अधिक फुरतीला है।

(ब) तीनों बच्चों में राजेश सबसे अधिक फुरतीला है।

(स) इसे जाना नहीं जा सकता है।

3. **कथन :**

—एरोमीनिया नामक कुकुरमुत्ता रोडोम्स का एक भाग है।

—रोडोम्स विषैले कुकुरमुत्ते होते है।

निष्कर्ष :

(अ) एरोमीनिया एक विषैला कुकुरमुत्ता है।

(ब) एरोमीनिया विषैला कुकुरमुत्ता नहीं है।

(स) इसे जाना नहीं जा सकता है।

4. **कथन :**

—अरूण किरण से अच्छा गाता है।

—किरण श्याम से अच्छा गाती है।

निष्कर्ष :

(अ) श्याम अरूण से अच्छा गाता है।

(ब) अरूण श्याम से अच्छा गाता है।

(स) इसे जाना नहीं जा सकता है।

5. **कथन :**

—अमर कल्पना से कम साहसी है।

—कल्पना विजय से कम साहसी है।

निष्कर्ष :

(अ) तीनों बच्चों में विजय सबसे अधिक साहसी है।

(ब) तीनों बच्चों में अमर सबसे अधिक साहसी है।

(स) इसे जाना नहीं जा सकता है।

भाग II

क्या आप अच्छे जासूस हैं ?

आप कुछ ऐसी छोटी समस्याओं को हल करने जा रहे हैं जिनमें कथन

थोड़े से जटिल हैं। आप अपने को जासूस की स्थिति में रखिये जो अपने जाँच के दौरान संकेतों (सूत्रों) को एकत्र करता है तथा अपने तर्क और अनुमान के द्वारा सच्चाई की खोज का प्रयत्न करता है। जासूस को जो कुछ कहा जाता है तथा वह जो कुछ देखता है, उसके आधार पर वह कुछ कल्पनायें करता है और सबूत की खोज करता है।

अब, नीचे दिये गये कथन के तीन वाक्यों को पढ़िए और ध्यानपूर्वक सोचते हुए यह पता लगाने की कोशिश कीजिए कि कथनों के नीचे जो परिणाम दिये गये हैं, वे सही हैं या गलत।

उदाहरण : कथन :

—यदि रमेश ने झूठ कहा था, तब शशिकान्त फुटबॉल खेलने गया था।

—यदि तेज धूप निकली थी, तब रमेश ने झूठ कहा था।

—लेकिन, आज यह पता चला कि वास्तव में तेज धूप निकली थी।

निष्कर्ष :

(अ) रमेश झूठ बोला था।

(ब) रमेश झूठ नहीं बोला था।

(स) शशिकान्त फुटबॉल खेलने गया था।

(द) शशिकान्त फुटबॉल खेलने नहीं गया था।

(इ) इसे जाना नही जा सकता है।

समस्या के दिये गये कथन से, पहले आप यह पता करने की कोशिश कीजिए कि रमेश झूठ बोला था या नहीं, और तब आप यह पता कर सकते हैं कि शशिकान्त फुटबॉल खेलने गया था या शशिकान्त फुटबॉल खेलने नहीं गया था।

आप पायेंगे कि यह निश्चित हो गया है कि रमेश झूठ बोला था क्योंकि वास्तव में तेज धूप निकली थी। अतः शशिकान्त फुटबॉल खेलने गया था क्योंकि रमेश झूठ बोला था।

उत्तर-पत्र में "स" और "अ" के नीचे के चौकोर खाने (□) में गुणा का निशान (×) लगाइए, क्योंकि यही दोनों जाँच के सही निष्कर्ष हैं।

आप पायेंगे कि इस भाग की प्रत्येक समस्या, यानि प्रश्न-संख्या ६ से ११ तक के लिए एक से अधिक उत्तर-सही हैं। आप प्रत्येक

समस्या को ध्यानपूर्वक पढ़िए और प्रत्येक समस्या (प्रश्न-संख्या 6 से 11 तक) के लिए जितने भी उत्तर आपको सही लगें उनको चुनने की कोशिश कीजिए।

6. **समस्या—कथन :**

—यदि चौकीदार ने चोरी में साथ दिया था, तो कमरे का दरवाजा खुला था या चोर ने तहखाने के रास्ते से प्रवेश किया।

—यदि चोरी अर्द्धरात्रि के समय हुई, तब चौकीदार ने चोरी में साथ दिया था।

—अब यह साबित हो गया है कि कमरे का दरवाजा खुला नहीं था तथा चोर ने तहखाने के रास्ते से प्रवेश नहीं किया।

निष्कर्ष :

(अ) चौकीदार ने चोरी में साथ नहीं दिया था।

(ब) चौकीदार ने चोरी में साथ दिया था।

(स) चोरी अर्द्धरात्रि के समय हुई थी।

(द) चोरी अर्द्धरात्रि के समय नहीं हुई थी।

(इ) यह जाना नहीं जा सकता कि चोरी अर्द्धरात्रि के समय हुई थी।

7. **समस्या—कथन :**

—दो में से एक बात : या तो चोर कार में आया था या गवाह गलती पर था।

—यदि चोर का किसी ने चोरी में साथ दिया था तो वह कार में आया था।

—चोर का कोई चोरी में साथ देनेवाला नहीं था और उसके पास कमरे की चाभी नहीं थी, या चोर के साथ कोई चोरी में साथ देनेवाला था और उसके पास कमरे की चाभी थी।

—अब यह साबित हो गया है कि चोर के पास कमरे की चाभी थी।

निष्कर्ष :

(अ) चोर कार में आया था।

(ब) चोर कार में नहीं आया था।

(स) गवाह गलती पर नहीं था।

(द) गवाह गलती पर था।

(इ) यह जाना नहीं जा सकता कि गवाह गलती पर था ।

8. **समस्या—कथन :**

—यदि पुलिस गलत रूप से खोज कर रही है तो समाचार पत्र झूठी खबरें दे रहे हैं ।

—यदि समाचार पत्र झूठी खबरें दे रहे हैं तो हत्यारा शहर में नहीं रहता है ।

—अब यह निश्चित हो गया है कि समाचार पत्र झूठी खबरें दे रहे हैं ।

निष्कर्ष :

(अ) हत्यारा शहर में रहता है ।

(ब) हत्यारा शहर में नहीं रहता है ।

(स) पुलिस गलत रूप से खोज कर रही है ।

(द) पुलिस गलत रूप से खोज नहीं कर रही है ।

(इ) यह जाना नहीं जा सकता कि पुलिस गलत रूप से खोज कर रही है ।

आप अपनी छुट्टियाँ कैसे व्यतीत करते हैं ।

अब आपको अपने तर्क और अनुमान के द्वारा पहले की ही तरह के प्रश्नों को हल करना है । लेकिन इनका सम्बन्ध छुट्टी के दिनों में समय व्यतीत करने के तरीकों से है । समस्या के कथनों से तर्क के आधार पर आपको यह पता करना है कि आप किन तरीकों से अपना मनोरंजन करने जा रहे हैं । उत्तर-पत्र पर सही उत्तर के नीचे बने चौकोर खाने (□) में गुणा का निशान [×] लगाते जाइए ।

9. **समस्या—कथन :**

—आप मित्रों के साथ बाहर जा रहे हैं, या आप पड़ोसियों के साथ गप्प कर रहे हैं ।

—यदि आप मित्रों के साथ बाहर जा रहे हैं, तो आप खेत पर जा रहे हैं या आप मछली मारने के लिए जा रहे हैं ।

—लेकिन, आप खेत पर नहीं जा रहे हैं और आप मछली मारने के लिए नहीं जा रहे हैं ।

निष्कर्ष :

(अ) आप मित्रों के साथ बाहर जा रहे हैं ।

(ब) आप मित्रों के साथ बाहर नहीं जा रहे हैं।
(स) आप पड़ोसियों के साथ गप्प कर रहे हैं।
(द) आप पड़ोसियों के साथ गप्प नहीं कर रहे हैं।
(इ) यह जाना नहीं जा सकता कि आप पड़ोसियों के साथ गप्प कर रहे हैं।

10. **समस्या—कथन :**

—यदि आप तैरने जा रहे हैं तो यह अच्छा मौसम है।
—यदि आप नौका-विहार के लिए जा रहे हैं तो यह अच्छा मौसम है।
—लेकिन, आप नौका-विहार के लिए जा रहे हैं।

निष्कर्ष :

(अ) यह अच्छा मौसम है।
(ब) यह अच्छा मौसम नहीं है।
(स) आप तैरने जा रहे हैं।
(द) आप तैरने नहीं जा रहे हैं।
(इ) यह जाना नहीं जा सकता कि आप तैरने जा रहे हैं।

11. **समस्या—कथन :**

—यदि कल वर्षा हुई थी तो आप फूल इकट्ठा करने जा रहे हैं, और यदि आप फूल इकट्ठा करने जा रहे हैं तो कल वर्षा हुई थी।
—दो में से एक चीज : या तो कल वर्षा हुई थी, या आप फुटबॉल खेलने जा रहे हैं।
—यदि आप फुटबॉल खेलने नहीं जा रहे हैं तो आप गाँव के पूरब की सड़क पर घूम रहे हैं।
—लेकिन, आप गाँव के पूरब की सड़क पर नहीं घूम रहे हैं।

निष्कर्ष :

(अ) आप फुटबॉल खेलने नहीं जा रहे हैं।
(ब) कल वर्षा नहीं हुई थी।
(स) आप फूल इकट्ठा करने जा रहे हैं।
(द) आप फूल इकट्ठा करने नहीं जा रहे हैं।
(इ) यह जाना नहीं जा सकता कि आप फूल इकट्ठा करने जा रहे हैं।

भाग III

समस्याओं के कथन को पढ़िए। इन कथनों के नीचे कई अलग-अलग उत्तर लिखे हुए हैं। **इन उत्तरों में केवल एक सही है** और बाकी गलत हैं। आपको सही उत्तर चुनना है और उत्तर-पत्र पर उस प्रश्न-संख्या के सामने दिये गये चौकोर खानों में से सही उत्तर वाले चौकोर खाने (□) में गुणा का निशान (×) लगाना है।

अब हम लोग पहली समस्या का अध्यन करने जा रहे हैं, जो कि एक उदाहरण है।

उदाहरण : कथन :

महेश और **अजय** ताश खेल रहे हैं। इस खेल में प्रत्येक खिलाड़ी 16 पत्ते पाता है। उन्हें ताशों को देखने का अधिकार नहीं है और वे अपने सामने उन्हें एक गड्डी बनाकर रखते हैं। प्रत्येक खिलाड़ी अपनी गड्डी के सबसे ऊपर का पत्ता उलटता है और जिसका पत्ता बड़ा होता है वह दो पत्ते जीत लेता है। जीते हुए पत्ते वह अपनी गड्डी के नीचे रख लेता है और खेल तब तक जारी रहता है जब तक कि एक खिलाड़ी अपने विरोधी के सारे पत्ते जीत नहीं लेता।

खेल शुरू में, **महेश** और **अजय** दोनों के पास 16, 16 पत्ते हैं। महेश के 16 पत्तों में 3 बादशाह हैं और अजय के 16 पत्तों में एक बादशाह है। अगली चाल में किस खिलाड़ी द्वारा बादशाह उलटने की सम्भावना अधिक है ?

(अ) **महेश**, क्योंकि उसके पास 16 पत्तों में 3 बादशाह हैं।
(ब) **अजय**, क्योंकि उसके पास 16 पत्तों में 1 बादशाह है।
(स) **महेश** और **अजय** की सम्भावनाएँ बराबर हैं क्योंकि उन दोनों के पास 16 पत्ते हैं।

दोनों के पास बराबर संख्या में पत्ते हैं, लेकिन **महेश** के पास 16 पत्तों में 3 बादशाह हैं जबकि अजय के पास 1 बादशाह है, अतः अगली चाल में महेश द्वारा पहले बादशाह उलटे जाने की सम्भावना अधिक है। इसलिए सही उत्तर **महेश** है। उत्तर-पत्र पर उदाहरण वाले स्थान पर "अ" के नीचे के चौकोर खाने (□) में गुणा का निशान (×) लगाइए।

अब इस भाग में प्रत्येक समस्या का केवल एक ही उत्तर सही है।

12. **समस्या :**

ताश के खेल के दूसरे चरण में : **महेश** की गड्डी में 22 पत्ते हैं जिनमें 2 इक्के हैं। **अजय** की गड्डी में 10 पत्ते हैं जिनमें 2 इक्के हैं। किस खिलाड़ी द्वारा पहले इक्का उलटने की अधिक सम्भावना है ?

(अ) **महेश,** क्योंकि उसके पास **अजय** से अधिक पत्ते हैं।
(ब) **अजय,** क्योंकि उसके पास कुल 10 पत्ते हैं जिसमें 2 इक्के हैं।
(स) **महेश** और **अजय** दोनों की सम्भावनाएँ हैं क्योंकि प्रत्येक के पास 2 इक्के हैं।

13. **समस्या :**

रामू के पास 15 गाय हैं जिसमें 7 काली और 8 सफेद रंग की हैं। **सोहन** के पास 15 गाय हैं जिसमें 5 काली और 10 सफेद हैं। दोनों अपनी गायों को अपनी-अपनी चहारदीवारी में रखते हैं। दोनों चहारदीवारी के फाटक से एक समय में केवल एक गाय निकल सकती है। जब रामू और सोहन अपनी गायों को चराने के लिए फाटक से निकालते हैं तो किसके फाटक से काली गाय को पहले निकलते हुए देखे जाने की सम्भावना अधिक है ?

(अ) **रामू** की चहारदीवारी से, क्योंकि उसके पास 15 गायों में से 7 काली गाय हैं।
(ब) **सोहन** की चहारदीवारी से. क्योंकि उसके पास 15 गायों में से 5 काली गाय हैं।
(स) दोनों के लिए सम्भावना बराबर है, क्योंकि प्रत्येक की चहारदीवारी में 15 गाय हैं।

14. **समस्या :**

5 बजे शाम को कारखाने में मजदूरों की छुट्टी होती है। कारखाने के बायें दरवाजे से 31 लोग बाहर निकलते हैं जिनमें 22 पुरुष और 9 औरतें हैं। कारखाने के दायें दरवाजे से 27 लोग बाहर निकलते हैं जिनमें 18 पुरुष और 9 औरतें हैं। दोनों में से किस दरवाजे से पहले औरत को निकलते हुए देखे जाने की सम्भावना सबसे अधिक है ?

(अ) **बायें दरवाजे से,** क्योंकि इससे अधिक लोग बाहर निकलेंगे।
(ब) **दायें दरवाजे से,** क्योंकि इससे कम पुरुष बाहर निकलेंगे।

(स) दोनों दरवाजों से सम्भावना बराबर है, क्योंकि प्रत्येक से 9 औरतें बाहर निकलेंगी।

15. **समस्या :**

व्यायाम की कक्षा में गेंद खेलने के लिए तीन टोलियाँ बनायी जाती हैं। पहली टोली में 6 छात्र और 1 गेंद, दूसरी टोली में 6 छात्र और 2 गेंद तथा तीसरी टोली में 12 छात्र और 3 गेंद हैं। आपको गेंद पकड़ने का ज्यादा से ज्यादा अवसर मिल सके इसके लिए आपको किस टोली में शामिल होना चाहिए ?

(अ) **तीसरी टोली** में शामिल होना बेहतर रहेगा क्योंकि इसमें अन्य टोलियों की अपेक्षा ज्यादा गेंद हैं।

(ब) **पहली टोली** में शामिल होना बेहतर रहेगा क्योंकि इसमें अन्य टोलियों की अपेक्षा कम छात्र हैं।

(स) **दूसरी टोली** में शामिल होना बेहतर रहेगा क्योंकि इसमें गेंद की तुलना में छात्रों की संख्या सबसे कम है।

(द) किसी एक टोली को नहीं चुना जा सकता क्योंकि दूसरी टोली में पहली टोली से एक गेंद और एक छात्र अधिक है और तीसरी टोली में बहुत अधिक छात्र हैं।

16. **समस्या :**

पहले गैराज (गाड़ियों को खड़ा करने का स्थान) में 24 गाड़ियाँ खड़ी की गयी हैं जिनमें 4 ट्रक और 20 कार हैं। दूसरे गैराज में 54 गाड़ियाँ हैं जिनमें 9 ट्रक और 45 कार हैं। तीसरे गैराज में 36 गाड़ियाँ हैं जिनमें 6 ट्रक और 30 कार हैं। किस गैराज से सर्वप्रथम ट्रक को निकलते हुए देखे जाने की सम्भावना सबसे अधिक है ?

(अ) **तीसरे गैराज** से, क्योंकि इसमें पहले गैराज से अधिक ट्रक हैं तथा दूसरे गैराज से कम कार हैं।

(ब) **दूसरे गैराज** से, क्योंकि इसमें सबसे अधिक ट्रक हैं।

(स) **पहले गैराज** से, क्योंकि इसमें सबसे कम कार हैं।

(द) किसी भी गैराज से, क्योंकि सभी ट्रकों की संख्या गाड़ियों की कुल संख्या की तुलना में बराबर है।

17. **समस्या :**

छठी कक्षा के तीन वर्गों (सेक्शन) में गणित के एक ही शिक्षक हैं और वे छात्रों को एक ही प्रश्न-पत्र देते हैं।

—छठी कक्षा के पहले वर्ग के 30 छात्रों में से 20 उत्तीर्ण थे और 10 अनुत्तीर्ण थे।

—छठी कक्षा के दूसरे वर्ग के 42 छात्रों में से 22 उत्तीर्ण थे और 20 अनुत्तीर्ण थे।

—छठी कक्षा के तीसरे वर्ग के 20 छात्रों में से 12 उत्तीर्ण थे और 8 अनुत्तीर्ण थे।

परीक्षा के परिणाम के आधार पर छठी कक्षा के किस वर्ग का परीक्षाफल सबसे अच्छा है।

(अ) **तीसरे वर्ग** का, क्योंकि इसमें 8 ही छात्र ऐसे थे जो अनुत्तीर्ण थे।

(व) **दूसरे वर्ग** का, क्योंकि इसमें अनुतीर्ण छात्रों की संख्या सबसे अधिक है।

(स) **पहले वर्ग** का, क्योंकि इसमें अनुत्तीर्ण छात्रों की तुलना में उत्तीर्ण छात्रों की संख्या सबसे अधिक है।

(द) पहले, दूसरे और तीसरे **वर्गों** का गणित में परीक्षाफल समान स्तर का है, क्योंकि तीनों वर्गों में अनुतीर्ण छात्रों की तुलना में उत्तीर्ण छात्रों की संख्या अधिक है।

18. **समस्या :**

एक मेले में **अमरनाथ** लॉटरी का एक टिकट खरीदता है। इस लॉटरी में 25 टिकट बेचे जायेंगे जिनमें से 5 पर इनाम होगा और 20 पर कोई इनाम नहीं होगा। उसकी बहन **रूमा** दूसरी लॉटरी का एक टिकट खरीदती है। रूमा की लॉटरी में 10 टिकट बेचे जायेंगे जिनमें से 2 पर इनाम होगा और 8 पर कोई इनाम नहीं होगा। उसकी दूसरी बहन **सुषमा** तीसरी लॉटरी का एक टिकट खरीदती है जिनमें 40 टिकट बेचे जायेंगे जिनमें 8 इनामवाले और 32 बिना इनामवाले होंगे। तीनों बच्चों में किसके इनामवाले टिकट पाने की सम्भावना सबसे अधिक है ?

(अ) **सुषमा,** क्योंकि उसकी लॉटरी में सबसे अधिक इनामवाले टिकट हैं।

(ब) **रूमा,** क्योंकि उसकी लॉटरी में सबसे कम बिना इनामवाले टिकट हैं ।

(स) **अमरनाथ,** क्योंकि उसकी लॉटरी में रूमा से अधिक इनामवाले टिकट हैं और सुषमा से कम बिना **इनामवाले** टिकट हैं ।

(द) तीनों बच्चों के इनामवाले टिकट पाने की सम्भावना बराबर है, क्योंकि तीनों लॉटरी में इनामवाले टिकटों की संख्या बिना इनाम-वाले टिकटों संख्या की तुलना में बराबर है ।

19. **समस्या :**

विनोद, संतोष और **रंजीता,** प्रत्येक चॉकलेट का एक-एक पैकेट खरीदते हैं । विनोद के पैकेट में 4 लाल चॉकलेट और 12 हरे चॉकलेट हैं । संतोष के पैकेट में 7 लाल चॉकलेट और 21 हरे चॉकलेट हैं । रंजीता के पैकेट में 6 लाल चॉकलेट और 18 हरे चॉकलेट हैं । यदि तीनों बिना देखे हुए अपने-अपने पैकेट से एक-एक चॉकलेट निकालते हैं तो किस बच्चे की लाल रंग की चॉकलेट पाने की सम्भावना सबसे अधिक हैं ?

(अ) **विनोद,** क्योंकि उसके पैकेट में सबसे कम हरे रंग की चॉकलेट हैं ।

(ब) **संतोष**, क्योंकि उसके पैकेट में सबसे अधिक लाल रंग की चॉक-लेट हैं ।

(स) **रंजीता,** क्योंकि उसके पैकेट में विनोद से अधिक लाल रंग के चॉकलेट हैं और संतोष से कम हरे रंग के चाक्लेट हैं ।

(द) तीनों बच्चों के लाल रंग के चॉकलेट पाने की सम्भावना बराबर है, क्योंकि तीनों थैलों में लाल रंग के चॉकलेट की संख्या चॉकलेट की कुल संख्या की तुलना में बराबर है ।

20. **समस्या :**

छात्रों का तीन दल अपने शिक्षकों की देखरेख में घूमने के लिए जा रहा है ।

—पहले दल में 14 लोग हैं जिनमे 12 छात्र और 2 शिक्षक हैं ।

—दूसरे दल में 8 लोग हैं जिनमें 7 छात्र और 1 शिक्षक हैं ।

—तीसरे दल में 25 लोग हैं जिनमे 21 छात्र और 3 शिक्षक हैं ।

तीनों में से किस दल की शिक्षकों द्वारा सबसे अच्छे ढंग से देखभाल हो रही है ?

(अ) **पहले दल** की सबसे अच्छे ढंग से देखभाल हो रही है, क्योंकि इसमें छात्रों की संख्या की तुलना मे सबसे अधिक शिक्षक हैं ।

(ब) **दूसरे दल** की सबसे अच्छे ढंग से देखभाल हो रही है, क्योंकि इसमे छात्रों की संख्या सबसे कम है ।

(स) **तीसरे दल** की सबसे अच्छे ढंग से देखभाल हो रही है, क्योंकि इसमे छात्रों की देखभाल करनेवाले शिक्षकों की संख्या सबसे अधिक है ।

(द) तीनों दलों की समान रूप से देखभाल हो रही है, क्योंकि पहले दल में 14 लोगों के लिए 2 शिक्षक हैं जिससे कि प्रत्येक 7 लोंगों पर 1 शिक्षक हैं, दूसरे दल में 7 छात्रों पर 1 शिक्षक है तथा तीसरे दल में 21 छात्रों के लिए 3 शिक्षक हैं जिससे कि प्रत्येक 7 छात्र के लिए 1 शिक्षक हैं ।

भाग IV

इस भाग में 8 प्रश्न हैं । सर्वप्रथम आप पहली समस्या, "नृत्य" के कथन को पढ़िये और जब आप उसका उत्तर पा चुके हों तों **उत्तरों को उत्तर-पत्र पर खींची गई लाइनों पर लिखिए ।**

ध्यान दीजिए : यह आवश्यक नहीं है कि आप सभी लाइनों को प्रयोग में लायें क्योंकि आवश्यकता से अधिक लाइने दी गई हैं ।

बाद में आप दूसरी समस्या "स्कूटर की सवारी" को हल कीजिये, फिर अन्य समस्याओं को लीजिए । सभी समस्याओं को हल करने की कोशिश कीजिए और हमेशा उत्तर-पत्र पर दी गयी लाइनों पर ही उत्तर को लिखिए ।

21. **समस्या—नृत्य** :

एक नृत्य समारोह मैं तीन नर्तक और तीन दर्तकियाँ आयीं हुई हैं । तीन नर्तक हैं :

धीरेन्द्र (ध), सत्येन्द्र (स) और **राजेन्द्र (र)**

तथा तीन नर्तकियाँ हैं :

निहारिका (न), अनामिका (अ) और **लतिका (ल)**

नृत्य के लिए एक नर्तक और एक नर्तकी को लेकर कौन-कौन से जोड़े सम्भव हो सकते हैं ?

प्रत्येक **नाचने वाले के नाम का पहला अक्षर** लेकर सभी को उत्तर-पत्र पर दी गई लाइनों पर लिखिए । एक सम्भव जोड़ा हो सकता है,

धीरेन्द्र और निहारिका। इसके लिए **'धन'** पहले से ही उत्तर-पत्र की प्रथम पंक्ति पर लिखा जा चुका है। नाचने वालों के एक जोड़े को एक पंक्ति पर लिखते हुए अन्य जोड़ों को लिखिए।

22. समस्या—स्कूटर की सवारी :

राजू (र), **संदीप (स)** और **उमेश (उ)** स्कूटर चलाना चाहते हैं। आप जानते हैं कि स्कूटर पर केवल दो सीट होती हैं--एक चलाने वाले के लिए और दूसरा पीछे बैठने वाले के लिए। दो मित्रों की प्रत्येक टोली में प्रत्येक मित्र एक बार स्कूटर चलाना चाहता है, अतः कुल मिलाकर दो-दो की तीन से अधिक टोलियाँ बनेंगी। अब आप यह बताइए कि चलाने वाले और पीछे बैठने वाले दो-दो मित्रों की कितनी टोलियाँ बन सकती हैं ? उत्तर पत्र पर प्रत्येक ऐसी टोली के **चालक के नाम का प्रथम अक्षर पहले** और **पीछे बैठनेवाले के नाम का प्रथम अक्षर बाद में** लिखिए। उदाहरण के लिए, उत्तर-पत्र पर पहले से ही **'रस'** लिखा जा चुका है जिसका अर्थ है 'र' अर्थात राजू स्कूटर चला रहा है और 'स' अर्थात संदीप स्कूटर की पिछली सीट पर बैठा हुआ है।

23. समस्या—इनामवाले टिकट :

इनाम पाने के लिए आप लॉटरी का एक टिकट खरीदते हैं। जितने टिकट बेचे गये हैं उनकी टिकट-संख्या केवल दो अंको की ही है। ये टिकट-संख्यएँ केवल 1, 2, 3 और 4 के अंकों से ही बनायी गयी हैं।

आपके टिकट की संख्या 11 है। आपके जीतने की सम्भावना कितनी है, यह ज्ञात करने के लिए आप ऊपर दिये गये अंकों से मिलकर बनने वाली **दो अंकों की सभी टिकट-संख्याओं को उत्तर-पत्र पर दी गई लाइनों पर लिखिए।** याद रखिए, एक लाइन पर केवल एक ही टिकट-संख्या लिखनी है। आपके खरीदे हुए टिकट की संख्या (संख्या 11) पहले से ही एक लाइन पर लिखी जा चुकी है।

24. समस्या :

1, 2, 3, 4 और 5 के अंकों के मेल से दो अंकों वाली **कुल कितनी** संख्याएँ बनेंगी ? मन में हीं गणना करके उत्तर को उत्तर-पत्र पर लिखिए।

25. समस्या : कुश्ती :

कमलेश (क), घनश्याम (घ), मारकण्डेय (म), अजय (अ),

ब्रजेश (ब) और **नरेन्द्र (न)** नाम के छः पहलवान कुश्ती के लिए अखाडे में उतरने वाले हैं।

यह जानने के लिए कि इनमें सबसे अधिक बलवान कौन है, यह तय किया गया कि सभी एक-दूसरे से बारी-बारी से लड़ेंगे।

उत्तर-पत्र में दी गयी लाइनों पर होनेवाली सभी कुश्तियों को लिखिए। प्रत्येक कुश्ती के दो पहलवानों के नाम को उनके नाम के पहले अक्षर से लिखिए। उदाहरण के लिए एक लाइन पर **'कघ'** पहले ही लिखा जा चुका है, जिसका अर्थ है कमलेश (क) और घनशयाम (घ) के बीच की कुश्ती। कुश्ती के एक मैच के लिए एक ही लाइन का प्रयोग कीजिए।

26. **समस्या :**

यदि ६ के बदले ७ पहलवान हो जांय और प्रत्येक को दूसरे से कुश्ती करनी पड़े तो कुल कितनी कुश्तियाँ लड़ी जाएँगी ? मन में ही गणना करके उत्तर को उत्तर-पत्र पर लिखिए।

27. **समस्या : नाश्ता :**

आप होटल में नाश्ता करने गये हैं। आप चाहते हैं कि प्रत्येक तरह के स्वादिष्ट नाश्ते का स्वाद लें। होटल में चार तरह के नाश्ते हैं :

—**पकौड़ी** (प), **समोसा** (स), **आलूचॉप** (अ) और **दहीवड़ा** (द)

सभी चीजों का स्वाद लेने के लिए **आप किस क्रम से चारों तरह के नाश्ते को खा सकते हैं ?** चारों तरह के नाश्ते का स्वाद लेने के **जितने भी क्रम सम्भव हो सकते हैं, उनको उत्तर-पत्र में दी गयी लाइनों** पर लिखिए। प्रत्येक तरह के नाश्ते का पूरा नाम लिखने की आवश्यकता नहीं है, बल्कि नाश्ते के नाम का पहला अक्षर-मात्र ही लिखना है।

उदाहरण के लिए, एक क्रम **'पसअद'** पहले ही उत्तर-पत्र में एक लाइन पर लिखा हुआ है जिसका अर्थ है आप पहले पकौड़ी (प), फिर समोसा (स), फिर आलूचॉप (अ) और अन्त में दहीबड़ा (द) खायेंगे। एक लाइन पर एक क्रम को लिखते हुए बाकी सभी सम्भव क्रमों को लिखिए।

28. **समस्या : दुकानें :**

एक नये मकान के निचले तल्ले पर चार दुकानों के लिए जगह निकाली गयी है। इसे चार लोगों—**एक होटल वाले (ह)** ने, एक **दर्जी (द)** ने, एक

सैलून वाले (स) ने और **एक किताब वाले (क)** ने किराये पर लेने के लिए मकान मालिक से कहा है। ये लोग इन चार दुकानों में से कोई भी दुकान चुन सकते हैं। आप उन सभी सम्भव क्रमों को लिखिए जिनमें ये लोग चारों दुकानों को चुन सकते हैं। होटल के लिए **'ह'**, दर्जी की दुकान के लिए **'द'**, सैलून के लिए **'स'**, तथा किताब वाले के लिए **'क'** अक्षरों का प्रयोग कीजिए।

आप पायेंगे कि उत्तर-पत्र की पहली लाइन पर **'हदसक'** पहले ही लिखा जा चुका है, जिसका अर्थ है बायीं तरफ पहली दुकान **होटलवाले (ह)** की, दूसरी दुकान **दर्जी (द)** की, तीसरी दुकान **सैलूनवाले (स)** की तथा दाहिनी तरफ चौथी दुकान **किताबवाले (क)** की होगी। अब एक लाइन पर एक क्रम को लिखते हुए बाकी सभी सम्भव क्रमों को लिखिए।

APPENDIX—II

उत्तर-पत्र

(F. O. L. P., F. O. P., F. C. O.)

नाम.................................पिता का नाम..............................

कक्षा.....................वर्ग..............................क्रमांक........................

जन्म तिथि..

विद्यालय का नाम ....

यदि आप किसी उत्तर को बदलना चाहते हैं तो उस चौकोर खाने को जिस पर आपने गुणा का निशान (×) लगाया है, पूरी तरह से भर दीजिए तथा जिस दूसरे उत्तर को आप चुनना चाहते हैं उसके सामने के चौकोर खाने (□) में गुणा का निशान (×) लगा दीजिए।

भाग I

	अ	ब	स
1.	□	□	□
2.	□	□	□
3.	□	□	□
4.	□	□	□
5.	□	□	□

भाग II

	अ	ब	स	द	इ
उदाहरण—	☐	☐	☐	☐	☐
6.	☐	☐	☐	☐	☐
7.	☐	☐	☐	☐	☐
8.	☐	☐	☐	☐	☐
9.	☐	☐	☐	☐	☐
10.	☐	☐	☐	☐	☐
11.	☐	☐	☐	☐	☐

भाग III

	अ	ब	स
उदाहरण—	☐	☐	☐
12.	☐	☐	☐
13.	☐	☐	☐
14.	☐	☐	☐

	अ	ब	स	द
15.	☐	☐	☐	☐
16.	☐	☐	☐	☐
17.	☐	☐	☐	☐
18.	☐	☐	☐	☐
19.	☐	☐	☐	☐
20.	☐	☐	☐	☐

भाग IV

21. धन

——— ——— ——— ——— ———

——— ——— ——— ——— ———

——— ——— ——— ——— ———

22. रस

——— ——— ——— ——— ———

——— ——— ——— ——— ———

——— ——— ——— ——— ———

23. 11

24. ________

25. कघ

26. ________

27. प स अ द

28. ह द स क

APPENDIX—III

Directions for Administration of Tarkik Chintan Parikshan

SAY : Do not open the test booklet until you are told to do so.

DO : Distribute one copy of the test booklet and answer sheet to each student.

SAY : Has anybody not received a copy of the test and an answer sheet ?

DO : Give such students a copy.

SAY : Write your name and other details on the answer sheet.

DO : Assist those students who need help.

SAY : You will mark your answers, to some of the questions, on the answer sheet. There are some questions whose answers you will write in the booklet. At the right time I will remind you to write your answers in the booklet.

Mark the answer of your choice by placing an 'X' in the appropriate box.

If you wish to change an answer on your answer sheet, fill in the box completely and mark an 'X' in the box of your choice.

Do *not* use an eraser.

Are there any questions at this time ?

DO : Respond to the questions.

SAY : There are four parts to this test.

At the bottom of certain pages there will be a statement that reads, "Do not turn the page until the signal is given." When you arrive at that point, and you have answered the questions up to there, you should close the booklet until you are instructed to turn the page.

You will be given a certain amount of time to complete different parts of the test.

The signal to begin will be, "You may begin." The signal to stop work will be, "Please stop working."

For each part, I will give you a one minute warning before your time is up.

Are there any questions at this time ?

DO : Respond to questions.

SAY : Please turn the page and follow the directions while I read them aloud.

DO : Read page one.

SAY : Are there any questions at this time ?

DO : Respond to the questions.

SAY : You may begin.

DO : Allow five minutes for completing questions 1 through 5. After four minutes have elapsed announce the time remaining.

SAY : One minute remaining.

DO : Allow the one minute to elapse.

SAY : Please stop working.

Turn to page three and follow the directions while I read them aloud.

DO : Read page three.

SAY : Are there any questions at this time ?

DO : Respond to questions.

SAY : Turn the page. You may begin.

DO : Allow fifteen minutes for completion of questions 6 through 11.

After fourteen minutes have elapsed, announce the time remaining.

SAY : One minute remaining.

DO : Allow the one minute to elapse.

SAY : Please stop working.

Turn to page seven and follow the directions while I read them aloud.

DO : Read page seven.

SAY : Are there any questions at this time ?

DO : Allow twenty-five minutes for completion of questions 12 through 20.

After twenty-four minutes have elapsed, announce the time remaining.

SAY : One minute remaining.

DO : Allow one minute to elapse.

SAY : Please stop working.

Turn to page twelve and follow the directions while I read them aloud.

DO : Read page twelve.

SAY : Are there any questions at this time ?

DO : Respond to questions.

SAY : You may begin.

DO : Allow thirty minutes for completion of questions 21 through 28.

After twenty-nine minutes have elapsed, announce the time remaining.

SAY : One minute remaining.

DO : Allow one minute to elapse.

SAY : Please stop working.

Close your booklet.

Place your answer sheet on top of your test booklets.

DO : Collect answer sheets and booklets.

SAY : Thank students for their cooperation.

APPENDIX—IV

Scoring Key for Tarkik Chintan Parikshan :

1.	अ		
2.	ब		
3.	अ		
4.	ब		
5.	अ		
उदाहरण :	अ	और	स
6.	अ	और	द
7.	अ	और	स
8.	ब	और	इ
9.	ब	और	स
10.	अ	और	इ
11.	ब	और	द

उदाहरण :	अ
12.	ब
13.	अ
14.	ब
15.	स
16.	द
17.	स
18.	द
19.	द
20.	अ
21.	ध न, ध अ, ध ल, स न, स अ, स ल, र न, र अ, र ल
22.	र स, र उ, स र, स उ, उ र, उ स

23.

11	21	31	41
12	22	32	42
13	23	33	43
14	24	34	44

24. 25

25.

क घ	घ म	म अ	अ ब	ब न
क म	घ अ	म ब	अ ब	
क अ	घ ब	म न		
क ब	घ न			
क न				

26. 21

27.

प स अ द	स प अ द	अ प स द	द प स अ
प स द अ	स प द अ	अ प द स	द प अ स
प द स अ	स अ प द	अ स प द	द स प अ
प द अ स	स अ द प	अ स द प	द स अ प
प अ स द	स द प अ	अ द प स	द अ प स
प अ द स	स द अ प	अ द स प	द अ स प

28.	ह द स क	द ह स क	स ह द क	क ह द स
	ह द क स	द ह क स	स ह क द	क ह स द
	ह स द क	द स ह क	स द क ह	क द ह स
	ह स क द	द स क ह	स द ह क	क द स ह
	ह क द स	द क ह स	स क ह द	क स ह द
	ह क स द	द क स ह	स क द ह	क स द ह

APPENDIX—V

भौतिकी में सम्प्रत्यय सम्प्राप्ति परीक्षण
—बल

CONCEPT ATTAINMENT TEST IN PHYSICS
—FORCE

BY :
S.B. BHATTACHARYA
N.N. PANDEY

ध्यान दीजिए : इस परीक्षण पुस्तिका पर किसी भी तरह का निशान नहीं लगाना है।

Revised Form of Dr. A. Pandey's Concept Attainment Test on **Force.**

निर्देश :

आपको भौतिकी के एक सम्प्रत्यय बल (Force) से सम्बन्धित कुछ प्रश्नों का उत्तार, उत्तर-पत्र पर देना है। प्रत्येक प्रश्न के चार सम्भावित उत्तर—**अ, ब, स, द**—दिये गये हैं। **इनमें केवल एक उत्तर सही है।** आप सही उत्तार को चुनिए और उत्तर-पत्र पर उस प्रश्न-संख्या के सामने दिये गये चौकोर खाने (□) में गुणा का निशान (×) लगा दीजिए।

उदाहरण के लिए, यदि प्रश्न-संख्या 25 के लिए आपको सही उत्तर **'ग'** लगता है तो उत्तर-पत्र पर उस सम्प्रत्यय (Concept) वाले हिस्से में प्रश्न-संख्या 25 के सामने दिये गये चौकोर खानों में से 'ग' के नीचेवाले चौकोर खाने (□) में गुणा का निशान (×) लगा दीजिए।

यदि आप किसी लिखे हुए उत्तर को बदलना चाहते हैं तो जिस चौकोर खाने में आपने गुणा का निशान लगाया है उसे पूरी तरह से भर दीजिए (जैसे : ■) और जिस दूसरे उत्तर को आप चुनना चाहते हैं, उसके सामने के चौकोर खाने (□) में गुणा का निशान (×) लगा दीजिए।

1. किसी बल के विषय में निम्न में से क्या सत्य **नहीं है** ?
   (अ) बल सदा सदिश राशि होता है।
   (ब) बल किसी गतिशील वस्तु की गति को बढ़ाता या घटाता है।
   (स) बल में सदा ऊर्जा आवश्यक या निहित होती है।
   (द) बल सदा विकर्षण पैदा करता है।

2. किसी गतिशील वस्तु पर गति की दिशा में जितना ही अधिक बल लगाया जायेगा :
   (अ) वस्तु में उतना ही अधिक त्वरण उत्पन्न होगा।
   (ब) वस्तु की गति की दिशा में उतना ही अधिक परिवर्तन होगा।
   (स) वस्तु में उतना ही अधिक मन्दन उत्पन्न होगा।
   (द) वस्तु की गति उतनी ही कम होती जायेगी।

3. जब दो पिण्ड एक सीधी रेखा में आपस में टकराते हैं तो टक्कर के बाद उन पर लगने वाले बलों का मान :
   (अ) बराबर एवं दिशायें समान होती हैं।
   (ब) बराबर किन्तु दिशायें विपरीत होती हैं।
   (स) भिन्न होता है और दिशायें विपरीत होती हैं।
   (द) भिन्न होता है पर दिशायें समान होती हैं।

4. किसी वस्तु के संवेग परिवर्तन की दर को निम्न में से क्या कहेंगे ?
   (अ) वस्तु द्वारा किया गया कार्य
   (ब) वस्तु पर खर्च हुई शक्ति
   (स) वस्तु पर लगाया गया बल
   (द) वस्तु पर डाला गया दबाव

5. निम्न में से कौन केवल आकर्षण बल का उदाहरण है ?
   (अ) दो चुम्बक जिनके समान ध्रुव एक दूसरे के सामने हैं
   (ब) तैरती हुई नाव
   (स) दो धनात्मक आवेश
   (द) सौर-मण्डल

6. एक ही द्रव्यमान की दो गेंदें X तथा Y एक दूसरे से टकराती हैं। गेंदों की गति की दिशा तथा त्वरण a नीचे के चित्र में दिखाये गये हैं।

X ---→ ←--- **Y**

a = 10मी/से.^{2} a = 20मी/से.^{2}

टकराव के बाद निम्न में से सही स्थिति क्या होगी ?

(अ) X ←----- -----→ Y

a = 20मी./से.^{2} a = 20मी./से.^{2}

(ब) X ←----- -----→ Y

a = 10मी./से.^{2} a = 20मी/से.^{2}

(स) X ←----- -----→ Y

a = 15मी/से.^{2} a = 15मी/से.^{2}

(द) X ←----------- Y

a = 30मी/से.^{2} स्थिर.

7. निम्न में से कौन सा बल का उदाहरण है ?
   (अ) वेग (Velocity)
   (ब)) गुरुत्व (Gravity)
   (स) संवेग (Momentum)
   (द) चाल (Speed)

8. निम्न में से कौन सी राशि सदिश है ?
   (अ) चाल
   (ब) संवेग
   (स) दिशा
   (द) द्रव्यमान

9. निम्न में से कौन सा उदाहरण बल को प्रदर्शित नहीं करता है ?
   (अ) भार
   (ब) घर्षण

(स) ध्वनि
(द) पृथ्वी पर गिरती हुई वस्तु

10. निम्न में से बल की सही परिभाषा क्या है ?
 (अ) दबाव परिवर्तन की दर को बल कहते हैं ।
 (ब) संवेग परिवर्तन की दर को बल कहते हैं ।
 (स) वेग परिवर्तन की दर को बल कहते हैं ।
 (द) दूरी परिवर्तन की दर को बल कहते हैं ।

11. किसी वस्तु के भार में :
 (अ) केवल परिमाण होता है, दिशा नहीं होती है ।
 (ब) परिमाण नहीं होता, केवल दिशा होती है ।
 (स) परिमाण और दिशा दोनों नहीं होते हैं ।
 (द) परिमाण और दिशा दोनों होते हैं ।

12. किसी भी परमाणु के इलेक्ट्रॉन उसके नाभिक से बंधे होते हैं क्योंकि :
 (अ) नाभिक और इलेक्ट्रॉन एक ही दिशा में गतिशील रहते हैं ।
 (ब) नाभिक और इलेक्ट्रॉन विपरीत दिशा में गतिशील रहते हैं ।
 (स) इलेक्ट्रॉनों के बीच एक प्रकार का बल कार्य करता है ।
 (द) इलेक्ट्रॉनों तथा नाभिक के बीच आकर्षण कार्य करता है, जो एक सदिश राशि है ।

13. सभी बलों के लिए निम्न में से क्या सत्य है ?
 (अ) उनका उद्गम सदा किसी पदार्थ से होता है ।
 (ब) वे किसी वस्तु में सदा त्वरण ही उत्पन्न करते हैं ।
 (स) वे किसी वस्तु में सदा गति उतपन्न करते हैं ।
 (द) वे सदा अपकर्षक (repulsive) होते हैं ।

14. निम्न में से कौन सा बल का उदाहरण है ?
 (अ) ऊर्जा
 (ब) कार्य
 (स) दबाव
 (द) घर्षण

15. निम्न में से किस उदाहरण में हमेशा बल का लगाना आवश्यक नहीं है ?
 (अ) एक निश्चित वेग से शून्य में चलती हुई बस्तु

(ब) पृथ्बी पर गिरता हुआ पत्थर
(स) पृथ्वी के चारों ओर घूमता हुआ चन्द्रमा
(द) पानी में तैरता हुआ आदमी

16. सभी प्रकार के बल :
(अ) अदिश राशि होते हैं।
(ब) सदिश राशि होते हैं।
(स) सदिश या अदिश कोई भी हो सकते हैं।
(द)) ऊपर दिये गये कथनों में से कोई भी सत्य नहीं है।

17. बल को कार्य्य करने के लिए **कम से कम** कितनी वस्तु / वस्तुओं का होना आवश्यक है ?
(अ) एक भी वस्तु का होना आवश्यक नहीं है।
(ब) एक वस्तु का होना आवश्यक है।
(स) दो वस्तुओं का होना आवश्यक है।
(द) तीन वस्तुओं का होना आवश्यक है।

18. किसी वस्तु पर बल के द्वारा उतपन्न प्रभाव निम्न में से किस पर निर्भर करता है ?
(अ) केवल बल के परिमाण और उसकी दिशा पर
(ब) केवल बल के परिमाण और उसके कार्य्य बिन्दु पर
(स) केवल बल की दिशा और उसके कार्य्य-बिन्दु पर
(द) बल के परिमाण, उसकी दिशा और उसके कार्य्य-बिन्दु तीनों पर

19. किसी वस्तु में बल के द्वारा उतपन्न त्वरण :
(अ) वस्तु के द्रव्यमान के व्युत्क्रमानुपाती और उस पर लगाये गये बल के समानुपाती होता है।
(ब) वस्तु के द्रव्यमान के समामुपाती और उस पर लगाये गये बल के व्युत्क्रमानुपाती होता है।
(स) वस्तु के द्रव्यमान और उस पर लगाये गये बल दोनों के समानुपाती होता है।
(द) वस्तु के द्रव्यमान और उस पर लगाये गये बल दोनों के व्युत्क्रमानुपाती होता है।

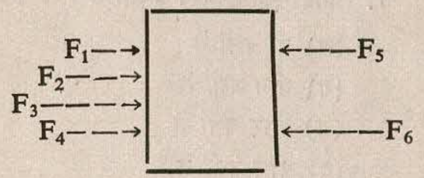
20. दिये गये चित्र में छः समानान्तर बल, F_1, F_2, F_3, F_4, F_5 और F_6 एक पिण्ड पर लग रहे हैं। इन बलों के प्रभाव के चलते वस्तु स्थिर अवस्था में पड़ी हुई है। इन बलों के लिए निम्न में से कौन सा समीकरण सही है ?

(अ) $F_1 + F_3 + F_5 = F_2 + F_4 + F_6$

(ब) $F_1 + F_2 + F_4 = F_3 - F_5 - F_6$

(स) $F_1 + F_2 + F_3 + F_4 = F_5 + F_6$

(द) $F_1 + F_2 - F_3 - F_4 + F_5 - F_6 = O$



APPENDIX—VI

भौतिकी में सम्प्रत्यय सम्प्राप्ति परीक्षण —बलयुग्म

CONCEPT ATTAINMENT TEST IN PHYSICS —COUPLE

BY :
S. B. BHATTACHARYA
N. N. PANDEY

निर्देश :

आपको भौतिकी के एक सम्प्रत्यय बल युग्म (Couple) से सम्बन्धित कुछ प्रश्नों का उत्तर, उत्तर-पत्र पर देना है। प्रत्येक प्रश्न के चार सम्भावित उत्तर—**अ, ब, स, द**—दिये गये हैं। **इनमें केवल एक उत्तर सही है।** आप सही उत्तर को चुनिए और उत्तर-पत्र पर उस प्रश्न-संख्या के सामने दिये गये चौकोर खाने (□) में गुणा का निशान (×) लगा दीजिए।

उदाहरण के लिए, यदि प्रश्न-संख्या 25 के लिए आपको सही उत्तर **'ग'** लगता है तो उत्तर-पत्र पर उस संप्रत्यय (Concept) वाले हिस्से में प्रश्न-सख्या 25 के सामने दिये गये चौकोर खानों में से **'ग'** के नीचेवाले चौकोर खाने (□) में गुणा का निशान (×) लगा दीजिए।

यदि आप किसी लिखे हुए उत्तर को बदलना चाहते हैं तो जिस चौकोर

ध्यान दीजिए : इस परीक्षण-पुस्तिका पर किसी भी तरह का निशान नहीं लगाना है।

खाने में आपने गुणा का निशान लगाया है उसे पूरी तरह से भर दीजिए (जैसे : ■) और जिस दूसरे उत्तर को आप चुनना चाहते हैं, उसके सामने के चौकोर खाने (□) में गुणा का निशान (×) लगा दीजिए।

1. कोई एक बलयुग्म बनता है :
   (अ) दो बलों से
   (ब) तीन बलों से
   (स) चार बलों से
   (द) पाँच बलों से

2. किसी बलयुग्म के लिए कौन सा कथन उपयुक्त है ?
   (अ) बलों का समान्तर होना आवश्यक है, पर परिमाण में बराबर होना आवश्यक नहीं है।
   (ब) बलों का समान्तर होना आवश्यक नहीं हैं पर परिमाण में बराबर होना आवश्यक है।
   (स) प्रयुक्त बलों को समान्तर और परिमाण में बराबर होना आवश्यक है।
   (द) बलों का न तो समान्तर और न ही परिमाण में बराबर होना आवश्यक है।

3. निम्न कथनों में बलयुग्म के लिए कौन कथन गलत है ?
   (अ) बल समान्तर होते हैं।
   (ब) बल परिमाण में बराबर होते हैं।
   (स) बलों की दिशाएँ विपरीत होती हैं।
   (द) बल एक ही बिन्दु पर कार्य करते हैं।

4. निम्न में से कौन सा बलयुग्म का उदाहरण है ?
   (अ) रस्सा-कसी के खेल में जब दोनों तरफ बराबर बल लग रहे हैं
   (ब) स्याही की दवात का ढक्कन खोलने में बल का प्रयोग
   (स) तैरते समय दोनों हाथों को खींचने में बल का प्रयोग
   (द) रोटी बेलने में बल का प्रयोग

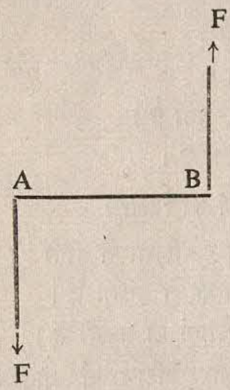
5. दिया गया चित्र प्रदर्शित करता है ?

   (अ) बलयुग्म

   (ब) बलयुग्म का आघूर्ण

   (स) बल का आघूर्ण

   (द) घर्षण



6. बलयुग्म का आघूर्ण किस पर निर्भर नहीं करता है ?

   (अ) बलों के परिणाम पर

   (ब) उस बिन्दु के, जिसके परितः उसका आघूर्ण लिया जाता है

   (स) बलों के बीच की लम्बवत् दूरी पर

   (द) बलों के परिमाण और उनके बीच की लम्बवत् दूरी दोनों पर

7. बलयुग्म के आघूर्ण में :

   (अ) केवल परिमाण होता है।

   (ब) केवल दिशा होती है।

   (स) परिमाण और दिशा दोनों नहीं होते हैं।

   (द) परिमाण और दिशा दोनों होते हैं।

8. किसी बलयुग्म के प्रभाव को संतुलित किया जा सकता है :

   (अ) केवल एक बलयुग्म के द्वारा जिसका आघूर्ण दिये हुए बलयुग्म के आघूर्ण के आसपास पर उसी दिशा में हो।

   (ब) केवल एक बलयुग्म के द्वारा जिसका आघूर्ण दिये हुए बलयुग्म के आघूर्ण से बड़ा पर विपरीत दिशा में हो।

(स) केवल एक बलयुग्म के द्वारा जिसका आघूर्ण दिये हुए बलयुग्म के आघूर्ण के बराबर पर विपरीत दिशा में हो।

(द) केवल एक बलयुग्म के द्वारा जिसका आघूर्ण दिये हुए बलयुग्म के आघूर्ण के बराबर पर उसी दिशा में हो।

9. यदि किसी पिण्ड पर लग रहे बलयुग्म के बलों के बीच की लम्बवत् दूरी बढ़ा दी जाय तो बलयुग्म के आघूर्ण का मान :

(अ) घट जाता है।

(ब) बढ़ जाता है।

(स) अपरिवर्तित रहता है।

(द) शून्य हो जाता है।

10. बलयुग्म के आघूर्ण की दिशा :

(अ) वामावर्त और दक्षिणावर्त दोनों हो सकती है।

(ब) केवल वामावर्त हो सकती है।

(स) केवल दक्षिणावर्त हो सकती है।

(द) वामावर्त और दक्षिणावर्त दोनों में से कोई भी नहीं हो सकती है।

11. निम्न में से कौन बलयुग्म का उदाहरण **नहीं** है।

(अ) लस्सी बनाते समय दही को मथने में किये गये बल का प्रयोग

(ब) ताला खोलने के लिए चाभी पर प्रयुक्त बल

(स) भौतिक तुला के दण्ड पर प्रयुक्त बल

(द) कार की स्टीयरिंग को दोनों हाथों से घुमाने पर प्रयुक्त बल

12. किसी पिण्ड पर लग रहे बलयुग्म के बलों का परिमाण कम कर दिया जाय तो बलयुग्म के आघूर्ण का मान :

(अ) अपरिवर्तित रहता है।

(ब) शून्य हो जाता है।

(स) बढ़ जाता है।

(द) कम हो जाता है।

13. किसी बलयुग्म के लिए कौन कथन हमेशा सही है ?

(अ) यह केवल घूर्णन गति उत्पन्न करता है।

(ब) यह केवल स्थानान्तरण गति उत्पन्न करता है ।

(स) यह घूर्णन और स्थानान्तरण दोनों तरह की गति उत्पन्न करता है ।

(द) यह न तो घूर्णन और न ही स्थानान्तरण गति उत्पन्न करता है ।

14. बलयुग्म के आघूर्ण का मात्रक है ?

(अ) न्यूटन

(ब) मीटर

(स) न्यूटन-मीटर

(द) जूल

15. निम्न में से किसमें बलयुग्म का प्रयोग होता है ।

(अ) नाव खेने में

(ब) भौतिक तुला में, जब दोनों पलड़ों पर बराबर भार हो

(स) भौतिक तुला में, जब दोनों पलड़ों पर बराबर भार नहीं हो

(द) पेंच खोलने या बन्द करने में

16. यदि किसी पिण्ड पर कई बलयुग्म एक तल में लग रहे हों तो :

(अ) उनको एक बलयुग्म के तुल्य माना जा सकता है जिसका आघूर्ण इन सभी आघूर्णो के बीजगणितीय योग के बराबर होता है ।

(ब) उनको एक बलयुग्म के तुल्य माना जा सकता है, जिसका आघूर्ण इन सभी आघूर्णो के गणितीय योग के बराबर होता है ।

(स) उनको एक बलयुग्म के तुल्य माना जा सकता है, जिसका आघूर्ण इन सभी आघूर्णो के गुणनफल के बराबर होता है ।

(द) उनको किसी एक बलयुग्म के तुल्य नहीं माना जा सकता है ।

17. निम्न कथनों में से कौन सही है ?

(अ) एक बल द्वारा किसी भी बलयुग्म को संतुलित किया जा सकता है, यदि उसका आघूर्ण वामावर्त दिशा में हो ।

(ब) एक बल द्वारा किसी भी बलयुग्म को संतुलित किया जा सकता है, यदि उसका आघर्ण दक्षिणावर्त दिशा में हो ।

(स) एक बल द्वारा किसी भी बलयुग्म को संतुलित नहीं किया जा सकता है।

(द) एक बल द्वारा किसी भी बलयुग्म को संतुलित किया जा सकता है, यदि उसका आघूर्ण बलयुग्म के आघूर्ण के बराबर और विपरीत दिशा में हो।

18. एक बलयुग्म में प्रयुक्त बलों में से एक मान 5 न्यूटन तथा उनके बीच की लम्बवत् दूरी 7 मीटर है। बलयुग्म का आघूर्ण होगा :

(अ) 12 न्यूटन

(ब) 2 मीटर

(स) 35 जूल

(द) 35 न्यूटन-मीटर

19. दो बराबर, विपरीत तथा समान्तर बल, जो एक सर। रेखा में नहीं हैं, किसी पिण्ड पर कार्य करते हैं, तो किसकी रचना करते हैं ?

(अ) घर्षण की

(ब) कार्य की

(स) शक्ति की

(द) बलयुग्म की

20. बलयुग्म की भुजा किसे कहते हैं ?

(अ) बलों के कार्य-बिन्दुओं को मिलाने वाली रेखा को

(ब) बलों के बीच की लम्बवत् दूरी को

(स) पिण्ड के गुरुत्व केन्द्र से बल की दूरी को

(द) बल और उस बिन्दु के बीच की दूरी को, जिसके परितः पिन्ड का आघूर्ण लिया जा रहा है

21. किसी पिन्ड में घूर्णन गति उत्पन्न करने के लिए :

(अ) केवल दो समान्तर बलों का एक ही दिशा में कार्य करना जरुरी है।

(ब) केवल दो समान्तर बलों का विपरीत दिशा में कार्य करना जरूरी है।

(स) दो समान्तर पर असमान बलों का कार्य करना जरूरी है।

(द) कई समान्तर समान बल, आधे एक दिशा में और आधे विपरीत दिशा में कार्य कर सकते हैं।

22. निम्न में से कौन बलयुग्म की सही परिभाषा है ?

(अ) जब दो बराबर, विपरीत तथा समान्तर बल, जो एक सरल रेखा में नही हैं. किसी पिण्ड पर कार्य करते हैं तो एक बलयुग्म की रचना होती है।

(ब) जब दो बराबर, विपरीत तथा समान्तर बल, जो एक सरल रेखा में हैं, किसी पिण्ड पर कार्य करते हैं तो एक बलयुग्म की रचना होती है।

(स) जब दो असमान, विपरीत तथा समान्तर बल, जो एक सरल रेखा में हैं, किसी पिण्ड पर कार्य करते हैं तो एक बलयुग्म की रचना होती है।

(द) जब दो असमान, विपरीत तथा समान्तर बल, जो एक सरल रेखा में नहींहैं, किसी पिण्ड पर कार्य करते हैं तो एक बल-युग्म की रचना होती है।

23. यदि बलयुग्म बनाने वाले बलों में से एक का मान F तथा बलयुग्म की भुजा A B हो तो बलयुग्म के आघूर्ण का मान होगा :

(अ) $F + AB$

(ब) $F \times AB$

(स) $F - AB$

(द) $F \div AB$

24. बलयुग्म और समान्तर बलों में क्या समानता है ?

(अ) दोनों हमेशा स्थानान्तरण गति उत्पन्न करते हैं।

(ब) दोनों हमेशा घूर्णन गति उत्पन्न करते हैं।

(स) दोनों मे बल हमेशा समान्तर होते हैं।

(द) दोनों में बल हमेशा एक ही दिशा में कार्य करते हैं।

APPENDIX—VII

भौतिकी में सम्प्रत्यय सम्प्राप्ति परीक्षण
—पूर्ण आन्तरिक परावर्तन

CONCEPT ATTAINMENT TEST IN PHYSICS
—TOTAL INTERNAL REFLECTION

BY :

S. B. BHATTACHARYA
N. N. PANDEY

निर्देश :

आपको भौतिकी के एक सम्प्रत्यय पूर्ण आन्तरिक परावर्तन (Total Internal Reflection) से सम्बन्धित कुछ प्रश्नों का उत्तर, उत्तर-पत्र पर देना है। प्रत्येक प्रश्न के चार सम्भावित उत्तर—**अ, ब, स, द**—दिये गये हैं। **इनमें केवल एक उत्तर सही है**। आप सही उत्तर को चुनिए और उत्तर-पत्र पर उस प्रश्न-संख्या के सामने दिये गये चौकोर खाने (□) में गुणा का निशान (×) लगा दीजिए।

उदाहरण के लिए, यदि प्रश्न-संख्या 25 के लिए आपको सही उत्तर 'ग' लगता है तो उत्तर-पत्र पर उस संप्रत्यय (Concept) वाले हिस्से में प्रश्न-सख्या 25 के सामने दिये गये चौकोर खानों में से 'ग' के नीचेवाले चौकोर खाने (□) में गुणा का निशान (×) लगा दीजिए।

यदि आप किसी लिखे हुए उत्तर को बदलना चाहते हैं तो जिस चौकोर खाने में आपने गुणा का निशान लगाया है उसे पूरी तरह से भर दीजिए (जैसे : ■) और जिस दूसरे उत्तर को आप चुनना चाहते हैं, उसके सामने के चौकोर खाने (□) में गुणा का निशान (×) लगा दीजिए।

ध्यान दीजिए : इस परीक्षण-पुस्तिका पर किसी भी तरह का निशान नहीं लगाना है।

1. जब प्रकाश की किरण सघन माध्यम से विरल माध्यम में जाती है तो :

   (अ) अपवर्तन कोण, आपतन कोण से बड़ा होता है।

   (ब) आपतन कोण, अपवर्तन कोण से बड़ा होता है।

(स) आपतन कोण और अपवर्तन कोण हमेशा बराबर होते हैं।
(द) आपतन कोण और अपवर्तन कोण में कोई सम्बन्ध नहीं होता है।

2. पूर्ण आन्तरिक परावर्तन के लिए आवश्यक है कि :
(अ) प्रकाश विरल माध्यम से सघन माध्यम में जा रहा हो।
(ब) प्रकाश सघन माध्यम से विरल माध्यम में जा रहा हो।
(स) प्रकाश एक हो माध्यम में अपवर्तित हो।
(द) प्रकाश पूर्ण रूप से विरल माध्यम में ही जा रहा हो।

3. क्रान्तिक कोण के लिए कौन कथन **गलत** है ?
(अ) क्रान्तिक कोण का मान प्रकाश के रंग पर निर्भर करता है।
(ब) क्रान्तिक कोण का मान माध्यम पर निर्भर करता है।
(स) क्रान्तिक कोण का मान न तो माध्यम और न ही प्रकाश क रंग पर निर्भर करता है।
(द) क्रान्तिक कोण का मान प्रकाश के रंग और माध्यम दोनों पर निर्भर करता है।

4. पूर्ण आन्तरिक परावर्तन के लिए कौन कथन हमेशा सही है ?
(अ) आपतन कोण का मान क्रान्तिक कोण से बड़ा होता है।
(ब) पूरा प्रकाश सघन माध्यम से विरल माध्यम में चला आता है।
(स) प्रकाश का कुछ भाग परावर्तित और कुछ भाग अवशोषित हो जाता है।
(द) ऊपर के तीनों कथनों में से कोई भी नहीं।

5. जिस आपतन कोण के लिए अपवर्तन कोण का मान 90° हो, उस कोण को :
(अ) आन्तरिक कोण कहते हैं।
(ब) विचलन कोण कहते हैं।
(स) क्रान्तिक कोण कहते हैं।
(द) ऊपर के तीनों में से कोई भी नहीं।

6. निम्न में से कौन पूर्ण आन्तरिक परावर्तन का उदाहरण है।
(अ) कालिख लगे गोले का पानी में चमकना

(ब) एक समतल दर्पण की सतह से परावर्तन

(स) काँच की एक चौकोर पट्टी से अपवर्तन

(द) तारों का टिमटिमाना

7. पूर्ण आन्तरिक परावर्तन के लिए कौन कथन सही है ?

(अ) अपवर्तन कोण, आपतन कोण से छोटा होता है।

(ब) अपवर्तन कोण, क्रान्तिक कोण से छोटा होता है।

(स) अपवर्तन कोण, आपतन कोण से बड़ा होता है।

(द) आपतन कोण, क्रान्तिक कोण से छोटा होता है।

8. जब प्रकाश की किरण सघन माध्यम से विरल माध्यम में जाते हुए पूरी तरह से सघन माध्यम में ही परावर्तित हो जाती है तो इसे क्या कहा जाता है ?

(अ) परावर्तन

(ब) अपवर्तन

(स) पूर्ण आन्तरिक परावर्तन

(द) विचलन

9. विरल माध्यम के सापेक्ष सघन माध्यम के अपवर्तनांक और क्रान्तिक कोण में क्या सम्बन्ध है ?

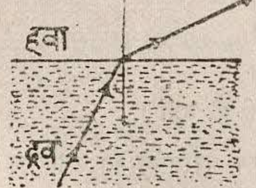
(अ) $r\mu d$ = Sin C

(ब) $r\mu d$ = 1/Sin C

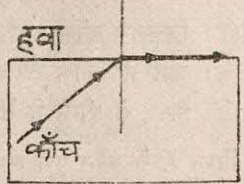
(स) $r\mu d$ = log Sin C

(द) $r\mu d$ = 1/Cos C

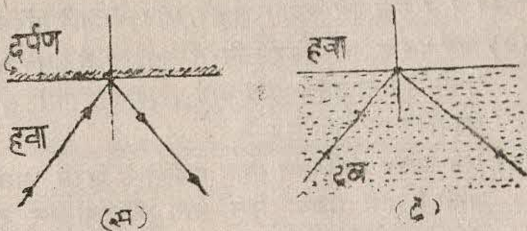
10. निम्न में से कौन पूर्ण आन्तरिक परावर्तन का उदाहरण है ?



(अ)



(ब)



11. निम्न में से कौन पूर्ण आन्तरिक परावर्तन का उदाहरण **नहीं** है ?
   (अ) चटखे हुए काँच का चमकना
   (ब) आकाश का नीला दिखाई पड़ना
   (स) हीरे का चमकना
   (द) पानी में रखी परख नली का चमकना

12. किस रंग के लिए क्रान्तिक कोण का मान सबसे सधिक होता है ?
   (अ) बैंगनी
   (ब) हरा
   (स) लाल
   (द) पीला

13. क्रान्तिक कोण और अपवर्तनांक में क्या सम्बन्ध है?
   (अ) जिस रंग के लिए क्रान्तिक कोण का मान अधिक होता है, उसका अपवर्तनांक अधिक होता है ।
   (ब) जिस रंग के लिए क्रान्तिक कोण का मान अधिक होता है, उसका अपवर्तनाँक कम होता है ।
   (स) जिस रंग के लिए क्रान्तिक कोण का मान कम होता है, उसका अपवर्तनांक कम होता है ।
   (द) क्रान्तिक कोण और अपवर्तनांक में कोई सम्बन्ध नहीं है ।

14. पूर्ण आन्तरिक परावर्तन होने पर प्रकाश की किरण :
   (अ) अपवर्तन के नियमों का पालन करती है ।
   (ब) परावर्तन के यिमों का पालन करती है ।
   (स) विचलन के नियमों का पालन करती है ।
   (द) ऊपर के तीनों में से किसी भी नियम का पालन नहीं करती है ।

15. निम्न में से कौन पूर्ण आन्तरिक परावर्तन की सही परिभाषा है ?
   (अ) जब प्रकाश की किरण विरल माध्यम से सघन माध्यम में जाती है तथा उसका कुछ भाग परावर्तित तथा कुछ भाग अपवर्तित हो जाता है।
   (ब) जब प्रकाश की किरण सघन माध्यम से विरल माध्यम में जाती है तथा उसका कुछ भाग अपवर्तित और कुछ भाग परावर्तित हो जाता है।
   (स) जब प्रकाश की किरण विरल माध्यम से सघन माध्यम में जाती है तथा उसका पूरा भाग अपवर्तित हो जाता है।
   (द) जब प्रकाश की किरण सघन माध्यम से विरल माध्यम में जाते समय सघन माध्यम में ही परावर्तित हो जाती है।

16. जब पूर्ण आन्तरिक परावर्तन हो जाता है तो :
   (अ) आपतन कोण ओर परावर्तन कोण बराबर होते हैं।
   (ब) आपतन कोण, परावर्तन कोण से बड़ा होता है।
   (स) आपतन कोण, परावर्तन कोण से छोटा होता है।
   (द) आपतन कोण और परावर्तन कोज में कोई निश्चित सम्बन्ध नहीं होता है।

17. जब प्रकाश की किरण अभिलम्ब से दूर भागे तो :
   (अ) वह विरल माध्यम से सघन माध्यम में जा रही होती है।
   (ब) वह सघन माध्यम से विरल माध्यम में जा रही होती है।
   (स) वह विरल माध्यम से सघन तथा फिर सघन माध्यम से विरल माध्यम में जा रही होती है।
   (द) ऊपर के तीनों विकल्पों में से कोई भी लागू नहीं होता है

18. निम्न में से किस उपकरण में पूर्ण आन्तरिक परावर्तन होता है ?
   (अ) टेलिस्कोप में
   (ब) माइक्रोस्कोप में
   (स) उस प्रिज्म में जिसके दो कोण 45°—45° के हों
   (द) एपीडायोस्कोप में

19. जब हम चाहते हैं कि परावर्तित प्रकाश बहुत ही चमकीला हो तो किस चीज का उपयोग करते हैं ?
   (अ) समतल दर्पण का

(ब) शीशे के चौकोर टुकड़े का
(स) प्रिज्म का, जिसका एक कोण 60° हो
(द) पूर्ण परावर्तक प्रिज्म का

20. यदि क्रान्तिक कोण का मान 60° हो तो विरल माध्यम के सापेक्ष सघन माध्यम का अपवर्तनांक होगा :

(अ) $\frac{2}{\sqrt{3}}$

(ब) $\frac{\sqrt{3}}{2}$

(स) $\log \frac{\sqrt{3}}{2}$

(द) $\frac{1}{2}$

APPENDIX—VIII

भौतिकी में सम्प्रत्यय सम्प्राप्ति परीक्षण —परमाणु

CONCEPT ATTAINMENT TEST IN PHYSICS —ATOM

BY :
S.B. BHATTACHARYA
N.N. PANDEY

ध्यान दीजिए : इस परीक्षण पुस्तिका पर किसी भी तरह का निशान नहीं लगाना है।

Revised Form of Dr. A. Pandey's Concept Attainment Test on **Atom.**

निर्देश :

आपको भौतिकी के एक सम्प्रत्यय परमाणु (Atom) से सम्बन्धित कुछ प्रश्नों का उत्तर, उत्तर-पत्र पर देना है। प्रत्येक प्रश्न के चार सम्भावित उत्तर— **अ, ब, स, द**—दिये गये हैं। **इनमें केवल एक उत्तर सही है।** आप सही उत्तर को चुनिए और उत्तर-पत्र पर उस प्रश्न-संख्या के सामने दिये गये चौकोर खाने (□) में गुणा का निशान (×) लगा दीजिए।

उदाहरण के लिए, यदि प्रश्न-संख्या 25 के लिए आपको सही उत्तर **'ग'** लगता है तो उत्तर-पत्र पर उस सम्प्रत्यय (Concept) वाले हिस्स में प्रश्न-संख्या 25 के सामने दिये गये चौकोर खानों में से 'ग' के नीचेवाले चौकोर खाने (□) में गुणा का निशान (×) लगा दीजिए।

यदि आप किसी लिखे हुए उत्तर को बदलना चाहते हैं तो जिस चौकोर खाने में आपपे गुणा का निशान लगाया है उसे पूरी तरह से भर दीजिए (जैसे : ■) और जिस दूसरे उत्तर को आप चुनना चाहते हैं, उसके सामने के चौकोर खाने (□) में गुणा का निशान (×) लगा दीजिए।

1. (अ) निम्न में से परमाणुओं के सम्बन्ध में क्या सत्य **नहीं** है ? किसी तत्व के सभी गुण उपस्थित होते हैं।
   (ब) प्रत्येक परमाण विद्युत उदासीन होता है।
   (स) विभिन्न तत्वों के परमाणुओं में न्यूट्रॉन की संख्या हमेशा समान होती है।
   (द) प्रत्येक परमाणु के मध्य में एक नाभिक होता है।
2. सबसे छोटे परमाणु की **नाभिक** में क्या होता है ?
   (अ) केवल एक प्रोट्रॉन
   (ब) केवल एक प्रोट्रॉन और एक न्यूट्रॉन
   (स) केवल एक प्रोट्रॉन और एक इलेक्ट्रॉन
   (द) केवल एक प्रोट्रॉन, एक न्यूट्रॉन और एक इलेक्ट्रॉन
3. किसी परमाणु के कणों के आवेश के बारे में क्या सत्य है ?
   (अ) परमाणु के सभी कणों (न्यूट्रॉन, प्रोट्रॉन तथा इलेक्ट्रॉन) पर धनात्मक आवेश होता है।
   (ब) न्यूट्रॉन तथा प्रोट्रॉन पर विपरीत आवेश होता है।
   (स) प्रोट्रॉन तथा इलेक्ट्रॉन पर विपरीत आवेश होता है।
   (द) परमाणु के सभी कणों पर ऋणात्मक आवेश होता है।
4. किसी भी तत्व का वह सूक्ष्मतम कण जिसमें उस तत्व के सभी गुण विद्यमान रहते हैं, उस तत्व का :
   (अ) अणु कहलाता है।
   (ब) नाभिक कहलाता है।
   (स) आयन कहलाता है।
   (द) परमाणु कहलाता है।

5. निम्न में से कौन परमाणुओं द्वारा **नहीं** बना है ?
   (अ) पानी
   (ब) कोशिका
   (स) हवा
   (द) ऊष्मा
6. एक आँक्सीजन परमाणु को धनात्मक आवेश वाले आयन में बदल दिया जाता है। अब उसमें :
   (अ) इलेक्ट्रॉन पहले से कम हो जायेंगे ।
   (ब) प्रोट्रॉन पहले से कम हो जायेंगे ।
   (स) प्रोट्रॉन पहले से अधिक हो जायेंगे ।
   (द) इलेक्ट्रॉन, प्रोट्रॉन के रूप में परिवर्तित हो जायेंगे ।
7. निम्न में से किसकी रचना परमाणुओं द्वारा होती है ?
   (अ) ध्वनि
   (ब) विद्युत् धारा
   (स) प्रकाश की किरण
   (द) गैस
8. परमाणु में **आवेश रहित** क्या होता है ?
   (अ) नाभिक
   (ब) प्रोट्रॉन
   (स) इलेक्ट्रॉन
   (द) न्यूट्रॉन
9. निम्न में कौन सा परमाणु का उदाहरण **नहीं** है ?
   (अ) N
   (ब) 2H
   (स) NH_4
   (द) 6S
10. परमाणु किसी :
    (अ) तत्व की सूक्ष्मतम इकाई है जिसमें उस तत्व के सभी गुण विद्यमान रहते हैं ।

(ब) मिश्रण (Mixture) की सूक्ष्मतम इकाई है जिसमें उस मिश्रण के भौतिक गुण विद्यमान रहते हैं।

(स) तत्व की सूक्ष्मतम इकाई है जिसमें उस तत्व के केवल भौतिक गुण विद्यमान रहते हैं।

(द) यौगिक (Compound) की सूक्ष्मतम इकाई है जिसमें उस यौगिक के सभी गुण विद्यमान रहते हैं।

11. निम्न में से किन कणों की संख्या प्रत्येक कार्बन परमाणु के **नाभिक** में समान होती है ?

(अ) इलेक्ट्रॉन तथा न्यूट्राँन

(ब) न्यूट्रॉन तथा प्रोट्रॉन

(स) प्रोट्रॉन तथा इलेक्ट्रॉन

(द) न्यूट्रॉन, प्रोट्रॉन णथा इलेक्ट्रॉन

12. सूत्र 'Cl' क्या प्रदर्शित करता है ?

(अ) क्लोरीन का एक अणु

(ब) क्लोरीन का एक आयन

(स) क्लोरीन का एक परमाणु

(द) क्लोरीन का एक यौगिक

13. निम्न में परमाणु के सम्बन्ध में क्या सत्य है ?

(अ) परमाणु एक ऋणात्मक आवेश वाला कण है।

(ब) परमाणु की रचना एक धनात्मक नाभिक एवं ऋणात्मक इलेक्ट्रॉनों द्वारा होती है।

(स) प्रत्येक परमाणु किसी दूसरे परमाणु के संयोग में ही पाया जा सकता है।

(द) परमाणु केवल गैसीय तत्वों में ही पाये जाते हैं।

14. निम्न में से कौन **अणु** का प्रतिनिधित्व करता है ?

(अ) Cl

(व) H_2

(स) C

(द) Na^+

15. निम्न में कौन कथन परमाणुओं के लिए **सत्य** है ?
    (अ) किसी तत्व का परमाणु स्वतन्त्र अवस्था में पाया जा सकता है ।
    (ब) किसी तत्व का परमाणु **केवल** उसी तत्व के परमाणुओं के संयोग (Combination) में ही पाया जा सकता है ।
    (स) किसी तत्व का परमाणु केवल दूसरे तत्व के परमाणुओं के संयोग में ही पाया जा सकता है।
    (द) ऊपर के तीनों कथनों में से कोई भी सही नहीं है ।
16. परमाणु एक प्रकार का / की :
    (अ) आवेश है ।
    (ब) प्रक्रिया है ।
    (स) मूल इकाई है ।
    (द) बल है ।
17. जब किसी तत्व के परमाणु दूसरे तत्व के परमाणु / परमाणुओं के साथ रासायनिक संयोग करते हैं तो किसकी रचना होती है ?
    (अ) दोनों में से किसी एक तत्व के अणु की
    (ब) यौगिक की
    (स) मिश्रण की
    (द) दोनों तत्वों के अलग-अलग अणओं की
18. मान लीजिए **X** तथा **Y** दो अलग-अलग तत्व हैं । इन तत्वों के परमाणुओं में :
    (अ) इलेक्ट्रॉन और प्रोट्रॉन दोनों की संख्या समान होगी ।
    (ब) इलेक्ट्रॉन की संख्या समान होगी, पर प्रोट्रॉन की संख्या भिन्न होगी ।
    (स) इलेक्ट्रॉन और प्रोटॉन दोनों की संख्या भिन्न होगी ।
    (द) इलेक्ट्रॉन की संख्या भिन्न होगी पर प्रोटॉन की संख्या समान होगी ।
19. प्रत्येक परमाणु :
    (अ) धनात्मक आवेश वाला होता है ।
    (ब) आवेश रहित होता है ।

(ब) मिश्रण (Mixture) की सूक्ष्मतम इकाई है जिसमें उस मिश्रण के भौतिक गुण विद्यमान रहते हैं।

(स) तत्व की सूक्ष्मतम इकाई है जिसमें उस तत्व के केवल भौतिक गुण विद्यमान रहते हैं।

(द) यौगिक (Compound) की सूक्ष्मतम इकाई है जिसमें उस यौगिक के सभी गुण विद्यमान रहते हैं।

11. निम्न में से किन कणों की संख्या प्रत्येक कार्बन परमाणु के **नाभिक** में समान होती है ?
    (अ) इलेक्ट्रॉन तथा न्यूट्रॉन
    (ब) न्यूट्रॉन तथा प्रोट्रॉन
    (स) प्रोट्रॉन तथा इलेक्ट्रॉन
    (द) न्यूट्रॉन, प्रोट्रॉन णथा इलेक्ट्रॉन

12. सूत्र 'Cl' क्या प्रदर्शित करता है ?
    (अ) क्लोरीन का एक अणु
    (ब) क्लोरीन का एक आयन
    (स) क्लोरीन का एक परमाणु
    (द) क्लोरीन का एक यौगिक

13. निम्न में परमाणु के सम्बन्ध में क्या सत्य है ?
    (अ) परमाणु एक ऋणात्मक आवेश वाला कण है।
    (ब) परमाणु की रचना एक धनात्मक नाभिक एवं ऋणात्मक इलेक्ट्रॉनों द्वारा होती है।
    (स) प्रत्येक परमाणु किसी दूसरे परमाणु के संयोग में ही पाया जा सकता है।
    (द) परमाणु केवल गैसीय तत्वों में ही पाये जाते हैं।

14. निम्न में से कौन **अणु** का प्रतिनिधित्व करता है ?
    (अ) Cl
    (व) H_2
    (स) C
    (द) Na^+

15. निम्न में कौन कथन परमाणुओं के लिए **सत्य** है ?
    (अ) किसी तत्व का परमाणु स्वतन्त्र अवस्था में पाया जा सकता है ।
    (ब) किसी तत्व का परमाणु **केवल** उसी तत्व के परमाणुओं के संयोग (Combination) में ही पाया जा सकता है ।
    (स) किसी तत्व का परमाणु केवल दूसरे तत्व के परमाणुओं के संयोग में ही पाया जा सकता है।
    (द) ऊपर के तीनों कथनों में से कोई भी सही नहीं है ।

16. परमाणु एक प्रकार का / की :
    (अ) आवेश है ।
    (ब) प्रक्रिया है ।
    (स) मूल इकाई है ।
    (द) बल है ।

17. जब किसी तत्व के परमाणु दूसरे तत्व के परमाणु / परमाणुओं के साथ रासायनिक संयोग करते हैं तो किसकी रचना होती है ?
    (अ) दोनों में से किसी एक तत्व के अणु की
    (ब) यौगिक की
    (स) मिश्रण की
    (द) दोनों तत्वों के अलग-अलग अणुओं की

18. मान लीजिए **X** तथा **Y** दो अलग-अलग तत्व हैं । इन तत्वों के परमाणुओं में :
    (अ) इलेक्ट्रॉन और प्रोट्रॉन दोनों की संख्या समान होगी ।
    (ब) इलेक्ट्रॉन की संख्या समान होगी, पर प्रोट्रॉन की संख्या भिन्न होगी ।
    (स) इलेक्ट्रॉन और प्रोटॉन दोनों की संख्या भिन्न होगी ।
    (द) इलेक्ट्रॉन की संख्या भिन्न होगी पर प्रोटॉन की संख्या समान होगी ।

19. प्रत्येक परमाणु :
    (अ) धनात्मक आवेश वाला होता है ।
    (ब) आवेश रहित होता है ।

(स) ऋणात्मक आवेश वाला होता है ।

(द) धनात्मक तथा ऋणात्मक दोनों तरह के आवेश वाला हो सकता है ।

20. किसी तत्व का परमाणु जब **उसी तत्व** के परमाणु के साथ संयोग करता है तो किसकी रचना होती है ?

(अ) उसी तत्व के अणु की

(ब) उसी तत्व के परमाणु की

(स) उसी तत्व के आयन की

(द) उसी तत्व के समस्थानिक (isotope) की

APPENDIX-IX

उत्तर-पत्र

भौतिकी में सम्प्रत्यय सम्प्राप्ति परीक्षण (CATP)

नाम..........................पिता का नाम.......................

विद्यालय.....................कक्षा...............क्रमांक.............

	बल (Force)					बलयुग्म (Couple)			
	अ	ब	स	द		अ	ब	स	द
1.	☐	☐	☐	☐	1.	☐	☐	☐	☐
2.	☐	☐	☐	☐	2.	☐	☐	☐	☐
3.	☐	☐	☐	☐	3.	☐	☐	☐	☐
4.	☐	☐	☐	☐	4.	☐	☐	☐	☐
5.	☐	☐	☐	☐	5.	☐	☐	☐	☐
6.	☐	☐	☐	☐	6.	☐	☐	☐	☐
7.	☐	☐	☐	☐	7.	☐	☐	☐	☐
8.	☐	☐	☐	☐	8.	☐	☐	☐	☐
9.	☐	☐	☐	☐	9.	☐	☐	☐	☐
10.	☐	☐	☐	☐	10.	☐	☐	☐	☐
11.	☐	☐	☐	☐	11.	☐	☐	☐	☐
12.	☐	☐	☐	☐	12.	☐	☐	☐	☐

13.	☐	☐	☐	☐
14.	☐	☐	☐	☐
15.	☐	☐	☐	☐
16.	☐	☐	☐	☐
17.	☐	☐	☐	☐
18.	☐	☐	☐	☐
19.	☐	☐	☐	☐
20.	☐	☐	☐	☐

13.	☐	☐	☐	☐
14.	☐	☐	☐	☐
15.	☐	☐	☐	☐
16.	☐	☐	☐	☐
17.	☐	☐	☐	☐
18.	☐	☐	☐	☐
19.	☐	☐	☐	☐
20.	☐	☐	☐	☐
21.	☐	☐	☐	☐
22.	☐	☐	☐	☐
23.	☐	☐	☐	☐
24.	☐	☐	☐	☐

पूर्ण आन्तरिक परावर्तन (Total Internal Reflection)

	अ	ब	स	द
1.	☐	☐	☐	☐
2.	☐	☐	☐	☐
3.	☐	☐	☐	☐
4.	☐	☐	☐	☐
5.	☐	☐	☐	☐
6.	☐	☐	☐	☐
7.	☐	☐	☐	☐
8.	☐	☐	☐	☐
9.	☐	☐	☐	☐
10.	☐	☐	☐	☐
11.	☐	☐	☐	☐
12.	☐	☐	☐	☐
13.	☐	☐	☐	☐
14.	☐	☐	☐	☐
15.	☐	☐	☐	☐
16.	☐	☐	☐	☐
17.	☐	☐	☐	☐
18.	☐	☐	☐	
19.	☐	☐	☐	☐
20.	☐	☐	☐	☐

परमाणु (Atom)

	अ	ब	स	द
1.	☐	☐	☐	☐
2.	☐	☐	☐	☐
3.	☐	☐	☐	☐
4.	☐	☐	☐	☐
5.	☐	☐	☐	☐
6.	☐	☐	☐	☐
7.	☐	☐	☐	☐
8.	☐	☐	☐	☐
9.	☐	☐	☐	☐
10.	☐	☐	☐	☐
11.	☐	☐	☐	☐
12.	☐	☐	☐	☐
13.	☐	☐	☐	☐
14.	☐	☐	☐	☐
15.	☐	☐	☐	☐
16.	☐	☐	☐	☐
17.	☐	☐	☐	☐
18.	☐	☐	☐	☐
19.	☐	☐	☐	☐
20.	☐	☐	☐	☐

APPENDIX-X

Scoring Key for Concept Attainment Tests in Physics :

प्रश्न सं.	बल	बलयुग्म	पूर्ण आन्तरिक परावर्तन	परमाणु
1.	द	अ	अ	स
2.	अ	स	ब	अ
3.	ब	द	स	स
4.	स	ब	अ	द
5.	द	अ	स	द
6.	स	ब	अ	अ
7.	ब	द	स	स
8.	ब	स	स	द
9.	स	ब	ब	स
10.	ब	अ	द	अ
11.	द	स	ब	ब
12.	द	द	द	स
13.	अ	अ	ब	ब
14.	द	स	ब	ब
15.	अ	द	द	अ
16.	ब	अ	अ	स
17.	स	स	ब	ब
18.	द	द	स	स
19.	अ	द	द	ब
20.	स	ब	अ	अ
21.		द		
22.		अ		
23.		ब		
24.		स		

APPENDIX—XI

केवल शोधकार्य हेतु गोपनीय

उ० अ० प०

Prepared by Miss Pritty Gandhi, under the guidance of Dr. S.S. Srivastava Faculty of Education, B. H. U.

इन्हें भरिये :

नाम...क्रमांक..............................

कक्षा..खण्ड..................................

विषय : (आर्ट / साइन्स / कामर्स)

विद्यालय का नाम ....

स्थायी निवास : (शहर / देहात)

पिता / अभिभावक का नाम :..

उनका व्यवसाय (पद का नाम लिखें यदि नौकरी में हों) :...............................

पिता / अभिभावक की शिक्षा :...

परिवार की मासिक आय :...

भाई बहनों की संख्या :............................ बड़े भाई...............................

छोटे भाई....................................बड़ी बहन..

छोटी बहन..

आपका जन्म क्रम : 1 ला , 2 रा , 3 रा , 4 था ,
5 वाँ , 6 वाँ , 7 वाँ , 8 वाँ ,

निर्देश :

इस सूची में आपके व्यवहार से सम्बन्धित कुछ बातें पूछी गई हैं । प्रत्येक बात के लिए पाँच सम्भावित उत्तर दिए गये हैं पाँचों उत्तरों को ध्यान से पढ़कर आपको यह बताना है कि कौन सा उत्तर आपके व्यवहार से मेल खाता है और उसी उत्तर के लिए दिये गये चौकोर में सही का $\boxed{\checkmark}$ चिन्ह लगा दें ।

ध्यान रखें कि आप किसी उत्तर को यह सोचकर न चुनें कि आपको 'क्या पसन्द करना चाहिए' और 'कैसा व्यवहार करना चाहिए' बल्कि यह सोचकर

चुनें कि आप सचमुच क्या पसन्द करते हैं, कैसा व्यवहार करते हैं। अर्थात् पाँचों उत्तरों में से कौन-सी बात आपके लिए ठीक ठीक लागू होती है।

इस सूची में कोई सही या गलत नहीं है क्योंकि इसका उद्देश्य केवल यह ज्ञात करना है कि विभिन्न परिस्थितियों में आप कैसा व्यवहार करते हैं।

प्रत्येक कथन का उत्तर अवश्य दें। उत्तर देने के लिए समय का कोई बन्धन नहीं है, किन्तु जितनी जल्दी हो सके काम पूरा करें। निःसंकोच और बेझिझक होकर उत्तर दें। आपके उत्तर एकदम गोपनीय रखे जायेंगे और केवल शोधकार्य के लिए प्रयोग किए जायेंगे।

1. मैं उसे एक अच्छा मित्र समझता हूँ जो :
   - ☐ चाहते है कि मैं हमेशा उसके बराबर का रहूँ।
   - ☐ मेरा सारा काम मेरे लिए करने की कोशिश करता है।
   - ☐ चाहता है कि मैं आगे बढ़ूँ।
   - ☐ चाहता है कि जीवन में मैं बहुत बड़ी सफलता प्राप्त करूँ।
   - ☐ मुझे मेरे काम में सहायता करता है।
2. मेरा विश्वास है कि सुख और आनन्द के लिए व्यक्ति को :
   - ☐ अपने को व्यस्त रखना चाहिए।
   - ☐ अपनी उपलब्धियों को और बढ़ाते रहना चाहिए।
   - ☐ मस्त और चिन्ता रहित रहना चाहिए।
   - ☐ कुछ लाभकारी कार्य करना चाहिए।
   - ☐ जीवन की आवश्यक सुविधाएँ मिलनी चाहिए।
3. यदि कोई कार्य मैं अच्छी तरह नहीं कर पाता हूँ तो मैं :
   - ☐ थोड़ा और परिश्रम करने की कोशिश करता हूँ।
   - ☐ निःसन्देह हो उस कार्य को छोड़कर कोई अन्य रुचिकर कार्य हाथ में लेता हूँ।
   - ☐ बेमन से उसमें लगा रहता हूँ।
   - ☐ हताश होकर उसे छोड़ने की सोचता हूँ।
   - ☐ उसमें निपुणता प्राप्त करने के लिए निरन्तर प्रयास करता हूँ।
4. मेरा पूरा विश्वास है कि दस साल के बाद मैं :
   - ☐ अपने क्षेत्र का एक विख्यात व्यक्ति बन जाऊँगा।

☐ अपना कार्य ठीक से कर रहा होऊँगा ।

☐ जहाँ मेरी परिस्थित ले जाएगीं वहीं जाऊँगा ।

☐ जो आज हूँ उससे कहीं अधिक अच्छा बन जाऊँगा ।

☐ जो मेरे भाग्य में लिखा होगा वही बन जाऊँगा ।

5. मुझे जीतना एव विजयी होना अच्छा लगता है :

☐ और में उसके लिए कठोर प्रयत्न करता हूँ ।

☐ किन्तु असफलता के डर से मैं प्रतियोगिता से दूर भागता हूँ ।

☐ और मैं उसके लिए कुछ कर सकता हूँ ।

☐ और मैं आशा करता हूँ कि जीत जाऊँगा ।

☐ परन्तु मैं शङ्कित रहता हूँ कि क्या मैं जीत पाऊँगा भी या नहीं ।

6. मुझे अच्छा लगता है :

☐ अपनी पिछली सफलताओं को याद करना और आनन्द लेना ।

☐ वर्तमान में जीना और एक-दो दिन के लिए योजना बनाना ।

☐ वर्तमान में जीना क्योंकि भविष्य अनिश्चित है ।

☐ भविष्य के विषय में अच्छी तरह सोचकर योजना बनाना ।

☐ पिछली बातों के विषय में विचारना और वर्तमान में किसी तरह जीवन चलाना ।

7. मैं एक ऐसा विषय पढ़ना चाहूँगा जो कि :

☐ बेशक न महत्वपूर्ण हो न उपयोगी, किन्तु जिसमें सफलता की पूर्ण सम्भावना हो ।

☐ महत्वपूर्ण और उपयोगी हो किन्तु जिसमें सफलता कीं सम्भावना भी हो ।

☐ महत्वपूर्ण और उपयोगी हो बेशक उसमें सफलता की सम्भावना कम ही क्यों न हो ।

☐ महत्वपूर्ण और उपयोगी न भी हो, परन्तु जिसमें सफलता की सम्भावना काफी हो ।

☐ साधारण और लोकप्रिय हो ।

8. यदि कोई कठिन कार्य करने में मैं अचानक सफल हो गया, तो मैं फिर चाहूँगा कि :

☐ उससे मिलता जुलता उसी स्तर का कोई और नया कार्य हाथ में ले लूँ।

☐ उससे काफी सरल काम हाथ में लूँ।

☐ उससे थोड़ा सा कठिन कार्य हाथ में लूँ।

☐ कोई भी नया कार्य हाथ में न लूँ क्योंकि कहीं असफल न हो जाऊँ।

☐ उससे कुछ सरल कार्य हाथ में लूँ।

9. मैं अपनै को :

☐ बहुत सन्तोषी व्यक्ति समझता हूँ।

☐ सामान्य आकांक्षा वाला व्यक्ति हूँ।

☐ बहुत कम आकांक्षा वाला व्यक्ति समझता हूँ।

☐ कम आकांक्षा वाला व्यक्ति समझता हूँ।

☐ उच्च आकांक्षा वाला व्यक्ति समेझता हूँ।

10. मुझे अक्सर लगता है कि मैं :

☐ व्यस्त रहता हूँ।

☐ व्यस्त नहीं रहता हूँ।

☐ खाली रहता हूँ और मेरे हाथ में काफी खाली समय रहता है।

☐ उतना व्यस्त नहीं रहता हूँ।

☐ कुछ न कुछ करने में बहुत व्यस्त रहता हूँ।

11. यदि किसी कठिन समस्या को हल करते समय मुझे एक सहयोगी चुनने को कहा जाए, तो मैं उसे चुनूँगा जो कि :

☐ बेशक अयोग्य हो किन्तु मेरा प्रिय दोस्त हो।

☐ ऊँचे दर्जे की योग्यता वाला हो और परिचित हो।

☐ मुझसे योग्य हो बेशक थोड़ा ही परिचित हो।

☐ बेशक मुझसे कम योग्य हो किन्तु काफी परिचित हो!

☐ सबसे योग्य हो बेशक कोई अनजान व्यक्ति ही क्यों न हो।

12. मेरे अनुसार एक ऐसा जीवन जिसमें किसी को कोई काम न करना हो :

☐ दुखदायी जीवन होगा।
☐ बहुत ही दुखदायी जीवन होगा।
☐ आदर्श जीवन होगा।
☐ सामान्य जीवन होगा।
☐ सुखमय जीवन होगा।

13. बिना ऊबे हुए मैं किसी काम को लगातार कर सकता हूँ।

☐ पाँच घण्टे से भी अधिक समय तक।
☐ तीन घण्टे तक।
☐ एक घण्टे से भी कम समय तक ही।
☐ चार घण्टे तक।
☐ दो घण्टे तक ही।

14. मैं एक सफल और प्रसिद्ध व्यक्ति बन सकता हूँ यदि :

☐ मेरा सही लोगों से सम्पर्क हो जाये तो।
☐ भाग्य मेरा साथ दे तो।
☐ मैं काम करू तो।
☐ मेरे माता पिता मेरी सहायता करें तो।
☐ मैं पूरी कोशिश करू तो।

15. मैं अच्छी तरह पढ़ना चाहता हू ताकि :

☐ कक्षा में सर्वश्रेष्ठ बनू।
☐ मुझे फिर से उसी कक्षा में पढ़ना पड़े।
☐ परीक्षा में पास हो जाऊ।
☐ अच्छे अंक ला सकू।
☐ माता-पिता मुझे दोषी न ठहराए।

16. मैं अधिकतर :

☐ एक-दो महीने आगे की सोचता हू।
☐ बहुत पहले गुजरी हुई बातों के विषय में सोचता हू।
☐ वर्तमान की सोचत। हू।

☐ अभी हाल में बीती हुई बातों के विषय में सोचता हू ।

☐ एक-दो वर्ष आगे की सोचता हू ।

17. यदि स्कूल की नुमाइश के लिए मुझे कुछ बनना पड़े, तो मैं ऐसे मॉडल और चार्ट बनाना चाहू गा ।

☐ जो मजेदार हो और अभी तक किसी ने न बनाया हो, भले ही उसमें उतना सफल हो पाऊँ या नहीं ।

☐ जिसे हमें स्कूल में बनाना सिखाया गया हो और बनाने के सामान उपलब्ध हो ।

☐ जो प्रचलित हो और जिसे बनाने में दूसरों की सहायता मिल सके ।

☐ जिसे अभी कम ही लोग जानते हो भले ही उसमें थोड़ी कठिनाई क्यों न हो ।

☐ जो प्रचलित हो और बिना कठिनाई के अक्सर सही बन जाता है ।

18. अक्सर मैं जितना काम करने की सोचता हू ।

☐ उससे बहुत कम कर पाता हू ।

☐ उससे थोड़ा अधिक कर लेता हू ।

☐ उससे कहीं अधिक कर लेता हू ।

☐ उससे थोड़ा कम ही कर पाता हूँ ।

☐ उतना ही कर पाता हू ।

19. मैं ऐसे लोगों को सराहना करता हूँ जिन्होने अपने पारिवारिक स्तर को :

☐ ऊँचा उठाया है ।

☐ ऊँचा उठाने के प्रयत्न में लगे हैं ।

☐ किसी तरह बनाये रखा है ।

☐ ऊँचा उठाने के इच्छुक हैं ।

☐ थोड़ा ऊँचा उठाया है ।

20. कितना अच्छा होता अगर एक दिन' में :

☐ 36 घण्टे होते ।

☐ केवल 12 घण्टे ही होते ।
☐ 30 घण्टे होते ।
☐ 24 घण्टे ही रहते ।
☐ केवल 18 घण्टे ही होते ।

21. मेरे लिए यह महत्व पूर्ण है कि, जिसके साथ मेरी घनिष्ठता हो वह :
☐ थोड़ा बहुत परिश्रमी हो और कुछ लोगों द्वारा चाहा जाता हो
☐ बहुतों द्वारा चाहा जाता हो ।
☐ बहुत परिश्रमी और सफल व्यक्ति हो ।
☐ परिश्रमी हो ।
☐ कुछ ही लोगों द्वारा चाहा जाता हो ।

22. मैं एक ऐसे अध्यापक के लिए कार्य करना पसन्द करूंगा जो :
☐ मेरे कार्य में मेरी सहायता करे ।
☐ मेरे लिए सारा कार्य कर दे ।
☐ मुझसे कठोर परिश्रम कराये ।
☐ मुझे कार्य करने के लिए उत्साहित करे ।
☐ मेरे सर्वोत्तम कार्य के अलावा मुझसे कुछ भी स्वीकार न करे ।

23. अक्सर मैं :
☐ कार्य तभी पूरा कर पाता हूँ जब कोई उत्साहित करता है ।
☐ यदि ऊबाने वाला कार्य हो तो उसे छोड़कर दूसरा कार्य चाहता हूँ ।
☐ किसी तरह कार्य पूरा कर ही लेता हूँ ।
☐ जब तक मन लगता है तभी तक कार्य करता हूँ ।
☐ जब तक कार्य पूरा न हो जाए उसमें लगा रहता हूँ ।

24. मेरा विश्वास है कि कोई भी :
☐ अपना भविष्य बनाने का मात्र, प्रयत्न कर सकता है किन्तु भविष्य अधिकतर उसके भाग्य पर निर्भर करता है ।
☐ काफी हद तक अपना भविष्य बना सकता है ।

☐ जैसा चाहे वैसा अपना भविष्य बना सकता है ।
☐ भाग्य के लिखे को नहीं बदल सकता है ।
☐ अपना भविष्य बनाने का प्रयत्न कर सकता है किन्तु भाग्य का भी उसमें हाथ होता है ।

25. स्कूल में, मैं सोचता हू कि :

☐ अच्छा करूँ ।
☐ पढ़ लिख जाऊँ ।
☐ बस पास हो जाऊँ ।
☐ सभी पुराने रिकार्ड तोड़ दूँ ।
☐ आसानी से पास होने का उपाय (Source) ढ़ूँढ़ लूँ ।

26. आजकल की परिस्थिति देखते हुए मुझे ऐसा लगता है कि :

☐ हमेशा भावी आवश्यकताओं की कल्पना करके, उनके अनुसार योजना बनानी चाहिए ।
☐ अक्सर आगे के लिए योजना बनानी चाहिए ।
☐ योजना ही नहीं बनानी चाहिए क्योंकि योजनाए कभी भी सफल नहीं होती है ।
☐ कभी कभी भविष्य के लिए योजना बना लेनी चाहिए ।
☐ बिरले ही कभी आगे के लिए योजना बनानी चाहिए ।

27. किसी पत्रिका में पहेली सामने आने पर मैं उसे हल करने का प्रयास करता हू :

☐ कभी कभी ।
☐ कभी भी नहीं ।
☐ हमेशा ।
☐ शायद ही कभी ।
☐ अधिकतर ।

28. बहुत अधिक जिम्मेदारी वाला काम :

☐ लेना मेरे लिए उचित नहीं होगा ।
☐ मैं तभी करूँगा जब मुझे पैसा मिलेगा ।
☐ मुझे बहुत अच्छा लगता है ।

☐ मैं लेना नहीं चाहूँगा ।
☐ मैं तभी करूँगा जब वह मेरी योग्यता के अनुसार होगा ।

29. मैं अपने पिता का उत्तराधिकार इसलिए सम्भावना चाहूगा क्यों कि :

☐ यह रीति/परिपाटी चली आ रही है ।
☐ मैं उनके किये गये कार्यों को और बढ़ाना एवं फैलाना चाहता हू ।
☐ मैं भाग्यशाली हूँ मेरे पिता के पास अपना कोई कार्य है ।
☐ धन प्राप्त करने का यह सबसे आसान तरीका है ।
☐ मैं अपने नये विचारों का प्रयोग उनके कार्यों में करना चाहता हूँ ।

30. जीवन में और अधिक आनन्द और सुख भोग के लिए मेरे पास :

☐ हमेशा समय रहता है ।
☐ कभी भी समय नहीं रहता है ।
☐ अधिकतम काफी समय रहता है ।
☐ कभी कभी बहुत थोड़ा समय रहता है ।
☐ अक्सर मेरे पास समय नहीं रहता है ।

APPENDIX-XII

ACHIEVEMENT MOTIVE INVENTORY KEY

Characteristics		Item Number	Alternatives & Scores 1st	2nd	3rd	4th	5th
Partner Choice	PC	1	3	1	4	5	2
		11	1	3	4	2	5
		21	3	1	5	4	2
Achievement Behaviour	AB	2	3	5	1	4	2
		12	4	5	1	3	2
		22	2	1	4	3	5

Characteristics		Item Number	Alternatives & Scores 1st	2nd	3rd	4th	5th
Persistence	P	3	4	1	3	2	5
		13	5	3	1	4	2
		23	4	1	3	2	5
Personal Responsibility	PR	4	5	3	2	4	1
		14	2	1	4	3	5
		24	2	4	5	1	3
Recognition Behaviour	RB	5	5	1	4	3	2
		15	5	2	3	4	1
		25	4	3	2	5	1
Time Perspective	TS	6	1	4	3	5	2
		16	4	1	3	2	5
		26	5	4	1	3	2
Risk Taking	RT	7	1	4	5	2	3
		17	5	3	1	4	2
		27	3	1	5	2	4
Aspiration level	AL	8	4	2	5	1	3
		18	1	4	5	2	3
		28	2	4	5	1	3
Upward Mobility	UM	9	1	4	2	3	5
		19	5	3	1	2	4
		29	1	5	2	3	4
Time Per-	TP	10	4	2	1	3	5
		20	5	1	4	3	2
		30	1	5	2	3	4

APPENDIX—XIII

गोपनीय

सामान्य मानसिक योग्यता परीक्षा

इस प्रश्न-पुस्तिका पर न तो कुछ लिखना है, और न किसी तरह का चिन्ह बनाना चाहिए। सभी उत्तरों को केवल दिये गये उत्तर-पत्र पर लिखना होगा।

प्रारम्भिक आदेश

इन प्रश्नों के द्वारा हम साधारण मानसिक योग्यता की परीक्षा करना चाहते हैं। २० मिनट में, आपको १०० प्रश्नों के उत्तर देने हैं।

इस परीक्षा के आरम्भ होने से पहले ही, इसमें दिये सब प्रकार के प्रश्नों को, और उनके उत्तर लिखने के नियमों को समझा दिया जायगा। सभी प्रश्न साधारण भाषा में लिखे हैं। प्रायः प्रश्नों के कुछ संभव उत्तर भी लिखे हुए हैं। उन दिये हुए उत्तरों में से आपको सबसे ठीक या सही उत्तर को चुनना है, और इसके बाद उस उत्तर के क्रमांक को, उत्तर पत्र पर उस प्रश्न के (क्रमांक के आगे) खाने में लिखना है। कैसे लिखना है, यह अभी बताया जायगा। **प्रत्येक प्रश्न का उत्तर, संख्या में देना है, अर्थात् अक्षरों में कुछ नहीं लिखना है। प्रत्येक प्रश्न का एक ही ठीक उत्तर है।** समय अधिक नहीं है, सब प्रश्नों का उत्तर बहुत कम लोग दे पाते हैं। अतएव आपको खूब शीघ्रता से काम करना चाहिये, और अधिक प्रश्नों का उत्तर देना चाहिये। अगर कोई प्रश्न आपको अधिक कठिन मालूम पड़े, तो उसे सोचने में अधिक समय नष्ट न कीजिये। उसे छोड़कर अगले प्रश्नों के उत्तर दीजिये। यदि अन्त में समय बचे तो छोड़े हुए प्रश्नों के उत्तर जानने की कोशिश कीजिये, और अपने उत्तरों को दुहरा लीजिये।

ध्यान रखिये कि इस प्रश्न पुस्तिका पर आपको कुछ नहीं लिखना है, और न उस पर किसी तरह का चिन्ह ही लगाना है।

अब पन्ना उलटिये और इसकी पीठ पर लिखे हुए उदाहरण ध्यान से पढ़िये।

अभ्यास के लिए उदाहरण

इस परीक्षा में जिस प्रकार के प्रश्न पूछे गये हैं, उनके उदाहरण नीचे दिये गये हैं। इनमें से कुछ के उत्तर-पत्र पर दिये गये हैं। इसके अतिरिक्त कुछ और भी प्रश्न हैं जिनके उत्तर आप स्वयम् सरलता से लिख सकेंगे।

आइये, अब हम इनको पढ़े :—

1. 'पर्वत' का अर्थ है—(1) पहाड़ (2) मैदान (3) ऊँचा (4) पत्थर
2. 'प्रधान' का अर्थ है—(1) धनी (2) कनुष्य (3) मार्ग (4) मुख्य
3. 'धनी' का उल्टा है—(1) विद्वान (2) दरिद्र (3) नीच (4) कमजोर
4. 'राजा' का उल्टा है—(1) साधु (2) प्रजा (3) बेटा (4) राज्य
5. 2, 3, 4, 5, 6.···। इन संख्याओं के क्रम के अनुसार आगे की एक संख्या उत्तर-पत्र पर लिखो।
6. 16, 13, 18, 15, 20,···। इन संख्याओं के क्रम के अनुसार आगे की एक संखया उत्तर-पत्र पर लिखो।
7. (1) कुर्सी (2) मेज (3) खाट (4) चूल्हा (5) कुत्ता—इन पाँचों में से किस एक का बाकी चारों से कुछ मेल नहीं है ?
8. (1) जापान (2) दिल्ली (3) चीन (4) भारत (5)—फ्रांस—इन पाँचों में से किस एक का बाकी चारों से कुछ मेल नहीं है ?
9. हम अंगीठी इसलिए रखते है कि—(1) वह हमें देखने में अच्छी लगती है। (2) वह गरमी देती है। (3) वह काली होती है। (4) उससे घर की शोभा होती है।
10. छाता लाभदायक वस्तु है क्योंकि—(1) वह हमें धूप व वर्षा से बचाता है। (2) वह कपड़े का बनता है। (3) वह सब जगह मिलता है। (4) वह हल्का होता है।
11. तीन बालक एक पंक्ति में बैठे हैं। प्रेम के दाहिने राम है। कृष्ण प्रेम की बाईं ओर है, तो बीच में कौन है ? (1) प्रेम (2) राम (3) कृष्ण।
12. अनन्त का जन्म गणेश से पहले हुआ। अनन्त से पहले रमेश पैदा हुआ, तो आयु में सबसे बड़ा कौन है ? (1) अनन्त (2) गणेश (3) रमेश।

13. जैसे आकाश : नीला, वैसे ही घास : (1) मेज (2) हरी (3) नरम (4) बड़ी ।

14. जैसे मछली : तैरना, वैसे मनुष्य : (1) कागज (2) खाना (3) चलना (4) देखना ।

यदि किसी को कोई शंका हो तो परीक्षा आरम्भ होने से पहिले पूछ लें । बाद में कुछ भी नहीं बताया जायगा ।

आरम्भ करने की आज्ञा मिलने पर ही उत्तर लिखना आरम्भ कीजिये, और जितनी शीघ्रता से हो उत्तर दीजिये ।

जब तक कहा न जाय

कृपया

इस पन्ने को मत उलटिये ।

1. जाड़ों में ऊनी कपड़े पहिने जाते हैं, क्योंकि—(1) वे कीमती होते हैं। (2) वे भारी होते हैं। (3) उनसे जाड़ा दूर होता है। (4) वे देर में धोये जाते हैं।
2. 'जल' का अर्थ है—(1) सरल (2) ज्वाला (3) जमीन (4) पानी।
3. (1) कुली (2) ईंट (3) दीवार (4) पत्थर (5) कंकड़—इन पाँचों में से किस एक का बाकी चारों से कुछ मेल नहीं है ?
4. 'पुण्य' का उल्टा है—(1) लोभ (2) पाप (3) अहकार (4) नीच।
5. 1, 2, 4, 8, 16,···इन संख्याओं के क्रम के अनुसार आगे की एक संख्या उत्तर-पत्र पर लिखो।
6. अपने से बड़ो का आदर करना चाहिए क्योंकि (1) उन्हें नाराज होने का अवसर नहीं मिलेगा। (2) वे आदर के पात्र हैं। (3) सब कहते हैं। (4) वे अधिक बलवान होते हैं।
7. (1) सोमवार (2) शनिवार (3) छुट्टी (4) रविवार (5) मंगलवार—इन पाँचों में से किस एक का बाकी चारों से कुछ मेल नहीं है ?
8. 'निर्भय' का अर्थ है—(1) साहसी (2) डरपोक (3) परिश्रमी (4) गर्वित।
9. सड़क पर बाईं ओर से ही चलना चाहिए क्योंकि—(1) बांया पैर हल्का होता है। (2) दाईं ओर ठोकर लगती है। (3) आने जाने में सुविधा होती है। (4) सड़क बहुत चौड़ी होती है।
10. कौवा (2) मोर (3) चील (4) मेंढक (5) बाज—इन पाँचों में से किस एक का बाकी चारों से कुछ मेल नहीं है ?
11. 2, 4, 6, 8, 10,···। इन संख्याओं के क्रम के अनुसार आगे की एक संख्या उत्तर-पत्र पर लिखो।
12. देव की आयु बासी से दुगुनी है परन्तु नवीन की आयु बासी से दो वर्ष कम है, तो सबसे छोटा कौन है ? (1) देव (2) बासी (3) नवीन।
13. 4, 7, 10, 13, 16,···। इन संख्याओं के क्रम के अनुसार आगे की एक संख्या उत्तर-पत्र पर लिखो।
14. मिट्टी, पानी से भारी है। पानी पत्थर से हल्का। पत्थर, लोहा से भारी होता है तो सबसे हल्का कौन है ? (1) मिट्टी (2) पानी (3) पत्थरे (4) लोहा।

15. 'आकाश' का उल्टा है—(1) पृथ्वी (2) महान (3) पाताल (4) शून्य ।
16. (1) मन (2) मस्तिष्क (3) आँख (4) कान (5) नाक—इन पाँचों में से किस एक का बाकी चारों से कुछ मेल नही हैं ?
17. 'युक्ति' का अर्थ है—(1) चेष्टा (2) उपाय (3) व्यर्थ (4) सफलता ।
18. गंगा नदी से सिन्धु छोटी है किन्तु घाघरा से बड़ी है । यदि यमुना और सिन्धु बराबर है परन्तु ब्रह्मपुत्र से छोटी है, तो कौन सबसे छोटी है ? (1) गंगा (2) सिन्धु (3) घाघरा (4) यमुना (5) ब्रह्मपुत्र ।
19. 'अपना' का उल्टा है—(1) आपका (2) मेरा (3) सबका (4) पराया ।
20. (1) किनारा (2) तालाब (3) समुद्र (4) नदी (5) नहर—इन पाँचों में से किस एक का बाकी चारों से कुछ मेल नहीं है ?
21. जैसे राम : आदमी, वैसे, ही कौवा : (1) पशु (2) चराचर (3) कोयल (4) पक्षी ।
22. (1) भवन (2) घर (3) झोपड़ी (4) कुटी (5) कार्यालय—इन पाँचों में से किस एक का वाकी चारों से कुछ मेल नहीं है ?
23. 'तरल' का उल्टा है—(1) ठोस (2) गरल (3) पानी (4) पत्थर ।
24. जैसे आदमी : हाथ, वैसे ही हाथी : (1) महावत (2) सूंड (3) दाँत (4) पाँव ।
25. 3, 9, 15, 21, 27,···इन संख्याओं के क्रम के अनुसार आगे की एक संख्या उत्तर-पत्र पर लिखो ।
26. जैसे प्रेमी : नायिका, वैसे ही भक्त : (1) देवता (2) सिद्धी (3) वरदान (4) भावना ।
27. (1) पुस्तक (2) कापी (3) कागज (4) रजिस्टर (5) स्याही—इन पाँचों में किस एक का बाकी चारों से कुछ मेल नहीं है ?
28. 4, 12, 20, 28, 36···इन संख्याओं के क्रम के अनुसार आगे की एक संख्या उत्तर-पत्र पर लिखो ।
29. जैसे माँ : बेटा, वैसे ही गाय : (1) भैंस (2) बैल (3) बछड़ा (4) बच्चा ।
30. 28, 25, 22, 19, 16···इन संख्याओं के क्रम के अनुसार आगे की एक संख्या उत्तर-पत्र पर लिखो ।

31. सरोज को बाँसुरी से सितार पसंद है परन्तु तबला नहीं चाहती है जब कि उसे वीणा से सितार कम पसंद है, तो उसे कौन सबसे अधिक पसंद है ? (1) बाँसुरी (2) सितार (3) तबला (4) वीणा ।

32. जैसे मनुष्य : बोलना, वैसे ही पक्षी : (1) गाना (2) कूकना (3) भूंकना (4) चहचहाना ।

33. 37, 30, 23, 16, 9···। इन संख्याओं के क्रम के अनुसार आगे की एक संख्या उत्तर-पत्र पर लिखो ।

34. जैसे पहिया : गाड़ी, वैसे ही नाव : (1) माँझी (2) तालाब (3) पत्वार (4) सड़क ।

35. टोपी पहिनना अच्छा है, क्योंकि—(1) इससे शान बढ़ती है । (2) इसे अधिकारी भी पहनते हैं । (3) यह सभ्यता का प्रतीक है । (4) यह सिर को धूप से बचाती है ।

35. जैसे वीर : कायर, वैसे ही हार : (1) विजय (2) डर (3) साहस (4) हर्ष ।

37. 96, 48, 24, 12, 6···। इन संक्याओं के क्रम के अनुसार आगे की एक सख्या उत्तार-पत्र पर लिखो ।

38. जैसे मकान : ईंट, वैसे ही कुर्सी : (1) पत्थर (2) लकड़ी (3) टाट (4) मेज ।

39. (1) रम्य (2) दाँई ओर (3) निकट (4) दूर (5) कहीं—इन पाँचों में से किस एक का बाकी चारों से कुछ मेल नहीं हैं ।

40. 64, 32, 16, 8, 4···। इन संख्याओं के क्रम के अनुसार आगे की एक संख्या उत्तर-पत्र पर लिखो ।

41. श्याम से राम चार वर्ष बड़ा है । संतोष से श्याम दो वर्ष छोटा है, तो कौन सबसे छोटा है ? (1) श्याम (2) राम (3) संतोष ।

42. मनुष्य को जीवन में नियमित रहना चाहिए, क्योंकि—(1) नियमित रहने वालों की आयु बड़ती है । (2) इससे कार्य-क्षमता बढ़ती है । (3) अनियमित लोग पागल हो जाते हैं । (4) नियम शास्त्रों में लिखे हैं ।

43. 15, 12, 9, 6, 3···। इन संख्याओं के क्रम के अनुसार आगे की एक संख्या उत्तर-पत्र पर लिखो ।

44. 'अर्न्तध्यान' का उल्टा है—(1) अदृश्य (2) प्रकट (3) गतिवान (4) गुप्त ।

45. जैसे माता : पिता, वैसे ही पुरुष : (1) स्त्री मनुष्य (3) नारी (4) शक्ति ।

46. 'प्रफुल्ल' का अर्थ है—(1) मुस्कान (2) उल्लसित (3) विराम (4) संतोष ।

47. जैसे पहाड़ : हिमालय, वैसे ही नदी : (1) सरिता (2) धारा (3) संगम (4) गंगा ।

48. (1) विदूषक (2) प्रेमी (3) प्रिय (4) मित्र (5) आत्मीय—इन पाँचों में से किस एक का बाकी चारों से कुछ मेल नहीं है ?

49. 'महिमा' का अर्थ है—(1) पुण्य (2) माहात्म्य (3) प्रशंसा (4) दिखावा ।

50. (1) बालक (2) तरुण (3) राम (4) वृद्ध (5) प्रौढ़—इन पाँचों में से किस एक का बाकी चारों से कुछ मेल नहीं है ?

51. 1, 3, 4, 6, 7···। इन संख्याओं के क्रम के अनुसार आगे की एक संख्या उत्तर-पत्र पर लिखो ।

52. जैसे आग : लपट, वैसे ही जल : (1) नदी (2) प्रताप (3) तट (4) धारा ।

53. (1) कुत्ता (2) सियार (3) गाय (4) बकरी (5) बैल—इन पाँचों में से किस एक का बाकी चारों से कुछ मेल नहीं है ?

54. जैसे छटाँक : मन, वैसे ही फरलांग : (1) कोस (2) गज (3) मील (4) सेर ।

55. 'प्राची' का उल्टा है—(1) उत्तर (2) प्रभात (3) आधुनिक (4) पश्चिम ।

56. 6, 7, 12, 14, 19···। इन संख्याओं के क्रम के अनुसार आगे की एक संख्या उत्तर-पत्र पर लिखो ।

57. प्रयाग की जनसंख्या देहली से कम किन्तु नैनीताल से अधिक है जब कि बम्बई स कलकत्ता की जनसख्या अधिक है । यदि देहली से बम्बई की जनसंख्या अधिक हो तो सबसे कम जनसंख्या कहाँ की है ?

(1) प्रयाग (2) देहली (3) नैनीताल (4) बम्बई (5) कलकत्ता ।

48. जैसे मोटर : घोड़ा, वैसे ही बालक : (1) रक्षक (2) मालिक (3) चतुर (4) सवार ।

49. 'वीर प्रसु' का अर्थ है—(1) बहादुर (2) वीर-माता (3) वैरागी (4) संताप ।

60. शीला से कोकिला अच्छा गाती है, लिकन सुमति से अम्बिका अच्छा गाती है । यदि कोकिला से सुमति अच्छा गाती है, तो कौन सबसे बुरा गाती है ? (1) शीला (2) कोकिला (3) सुमति (4) अम्बिका ।

61. प्राणी तभी तक जीवित रहता है जब तक—(1) उसे जीना होता है । (2) वह भोजन करता है । (3) वह बीमार नहीं होता है । (4) हृदय गतिवान रहता है ।

62. (1) पढ़ना (2) सोना (3) लिखना (4) बोलना (5) हसना—इन पाँचों में से किस एक का बाकी चारों से कुछ मेल नहीं है ?

63. हर एक लेखक कवि नहीं हो सकता है, क्योंकि—(1) बालक कहानियाँ पसन्द करते हैं । (2) कवि को कष्ट सहना होता है । (3) सबमें एक सी प्राकृतिक प्रतिभा नहीं होती है । (4) कवि शिष्यों से झगड़ा करते हैं ।

64. (1) इतिहास (2) भूगोल (3) गणित (4) परीक्षा (5) भाषा—इन पाँचों में से किस एक का बाकी चारों से मेल नहीं है ?

65. 2, 5, 9, 14, 20,···। इन संख्याओं के क्रम के अनुसार आगे की एक संख्या उत्तर-पत्र पर लिखो ।

66. (1) सेव (2) अमरूद (3) आम (4) कटहल (5) पपीता—इन पाँचों में से किस एक का बाकी चारों से मेल नहीं है ?

67. नारायण एक काम को चार घंटे में पूरा करता है तो गोपाल उसे सात घंटे में जब कि मदन उसके आधे काम को तीन घन्टे में पूरा कर लेता ज । यदि बलबीर उसके दुगुने काम को छ: घन्टे में पूरा करता है तो देर में कौन पूरा करता ? (1) नारायण (2) गोपाल (3) मदन (4) बलबीर ।

68. 56, 50, 45, 41, 38,···। इन संख्याओं के क्रम के अनुसार आगे की एक संख्या उत्तर-पत्र पर लिखो ।

69. समुद्र में बाढ नहीं आती है, क्योंकि (1) कुछ पानी के पहले ही मान-सून बन जाने से उसका आयतन कम होता है। (2) उसका पानी खारा होता है। (3) बहुत गहरा होता है। (4) अन्यथा प्रलय हो जायगा।

70. 3, 6, 10, 15, 21,... | इन संख्याओं के क्रम के अनुसार आगे की एक संख्या उत्तर-पत्र पर लिखो।

71. जैसे स्वामी : सेवक, वैसे ही राजा : (1) नागरिक (2) पंच (3) मंत्री (4) रंक।

72. 45, 40, 36, 33, 31,... | इन संख्याओं के क्रम के अनुसार आगे की एक संख्या उत्तर-पत्र पर लिखो।

73. जैसे कविता : निबन्ध, वैसे ही लेखक : (1) कलाकार (2) कवि (3) कहानी (4) सम्पादक।

74. परीक्षा में श्यामा से पुष्पा ने अधिक नम्बर पाये परन्तु कमला से कम पाये। कमला को प्रमीला से पाँच नम्बर कम मिले, जब कि प्रमीला और इन्दु को बराबर नम्बर मिले तो सबसे कम नम्बर किसने पाये ? (1) श्यामा (2) पुष्पा (3) कमला (4) प्रमीला (5) इन्दु।

65. 16, 13, 22, 19, 28,... | इन संख्याओं के क्रम के अनुसार आगे की एक संख्या उत्तर-पत्र पर लिखो।

76. जैसे नाटक : युद्ध, वैसे ही नायक : (1) सिपाही (2) नटी (3) अभिनव (4) पात्र।

77. 1, 5, 10, 16, 23,...। इनसंख्याओं के क्रम के अनुसार आगे की एक संख्या उत्तर पत्र पर लिखो।

78. क्रोध में कोई भी कार्य नहीं करना चाहिए, क्योंकि—(1) कार्य बिगड जाता है। (2) उस समय विवेक नहीं रहता है। (3) कर्य प्रेम से करना चाहिए। (4) पिटने का भय रहता है।

79. (1) घोड़ा (2) गधा (3) ऊँट (4) हाथी (5) गाय—इन पाँचों में से किस एक का बाकी चारों से कुछ मेल नहीं है ?

80. 4, 4, 5, 7, 10,...। इन संख्याओं के क्रम के अनुसार आगे की एक संख्या उत्तर-पत्र पर लिखो।

81. जैसे प्राणी : पत्थर, वैसे ही जीवित : (1) चेतन (2) (अचल) (3) निर्जीव (4) कंकड़।

82. (1) ऊवधि *(2)* अब (3) परसों 4) दिन (5) सप्ताह—इन पाँचों में से किस एक का बाकी चारों से कुछ मेल नही है ?

(1) प्रयाग (2) देहली (3) नैनीताल (4) बम्बई (5) कलकत्ता ।

48. जैसे मोटर : घोड़ा, वैसे ही बालक : (1) रक्षक (2) मालिक (3) चतुर (4) सवार ।

49. 'वीर प्रसु' का अर्थ है—(1) बहादुर (2) वीर-माता (3) वैरागी (4) संताप ।

60. शीला से कोकिला अच्छा गाती है, लिकन सुमति से अम्बिका अच्छा गाती है । यदि कोकिला से सुमति अच्छा गाती है, तो कौन सबसे बुरा गाती है ? (1) शीला (2) कोकिला (3) सुमति (4) अम्बिका ।

61. प्राणी तभी तक जीवित रहता है जब तक—(1) उसे जीना होता है । (2) वह भोजन करता है । (3) वह बीमार नहीं होता है । (4) हृदय गतिवान रहता है ।

62. (1) पढ़ना (2) सोना (3) लिखना (4) बोलना (5) हंसना—इन पाँचों में से किस एक का बाकी चारों से कुछ मेल नहीं है ?

63. हर एक लेखक कवि नहीं हो सकता है, क्योंकि—(1) बालक कहानियाँ पसन्द करते हैं । (2) कवि को कष्ट सहना होता है । (3) सबमें एक सी प्राकृतिक प्रतिभा नहीं होती है । (4) कवि शिष्यों से झगड़ा करते हैं ।

64. (1) इतिहास (2) भूगोल (3) गणित (4) परीक्षा (5) भाषा—इन पाँचों में से किस एक का बाकी चारों से मेल नहीं है ?

65. 2, 5, 9, 14, 20,···। इन संख्याओं के क्रम के अनुसार आगे की एक संख्या उत्तर-पत्र पर लिखो ।

66. (1) सेव (2) अमरूद (3) आम (4) कटहल (5) पपीता—इन पाँचों में से किस एक का बाकी चारों से मेल नहीं है ?

67. नारायण एक काम को चार घंटे में पूरा करता है तो गोपाल उसे सात घंटे में जब कि मदन उसके आधे काम को तीन घन्टे में पूरा कर लेता ज । यदि बलबीर उसके दुगुने काम को छः घन्टे में पूरा करता है तो देर में कौन पूरा करता ? (1) नारायण (2) गोपाल (3) मदन (4) बलबीर ।

68. 56, 50, 45, 41, 38,···। इन संख्याओं के क्रम के अनुसार आगे की एक संख्या उत्तर-पत्र पर लिखो ।

69. समुद्र में बाढ नहीं आती है, क्योंकि (1) कुछ पानी के पहले ही मान-सून बन जाने से उसका आयतन कम होता है। (2) उसका पानी खारा होता है। (3) बहुत गहरा होता है। (4) अन्यथा प्रलय हो जायगा।

70. 3, 6, 10, 15, 21,... | इन संख्याओं के क्रम के अनुसार आगे की एक संख्या उत्तर-पत्र पर लिखो।

71. जैसे स्वामी : सेवक, वैसे ही राजा : (1) नागरिक (2) पंच (3) मंत्री (4) रंक।

72. 45, 40, 36, 33, 31,... | इन संख्याओं के क्रम के अनुसार आगे की एक संख्या उत्तर-पत्र पर लिखो।

73. जैसे कविता : निबन्ध, वैसे ही लेखक : (1) कलाकार (2) कवि (3) कहानी (4) सम्पादक।

74. परीक्षा में श्यामा से पुष्पा ने अधिक नम्बर पाये परन्तु कमला से कम पाये। कमला को प्रमीला से पाँच नम्बर कम मिले, जब कि प्रमीला और इन्दु को बराबर नम्बर मिले तो सबसे कम नम्बर किसने पाये ? (1) श्यामा (2) पुष्पा (3) कमला (4) प्रमीला (5) इन्दु।

65. 16, 13, 22, 19, 28,... | इन संख्याओं के क्रम के अनुसार आगे की एक संख्या उत्तर-पत्र पर लिखो।

76. जैसे नाटक : युद्ध, वैसे ही नायक : (1) सिपाही (2) नटी (3) अभि-नव (4) पात्र।

77. 1, 5, 10, 16, 23,...। इनसंख्याओं के क्रम के अनुसार आगे की एक संख्या उत्तर पत्र पर लिखो।

78. क्रोध में कोई भी कार्य नहीं करना चाहिए, क्योंकि—(1) कार्य बिगड जाता है। (2) उस समय विवेक नहीं रहता है। (3) कर्य प्रेम से करना चाहिए। (4) पिटने का भय रहता है।

79. (1, घोड़ा (2) गधा (3) ऊँट (4) हाथी (5) गाय—इन पाँचों में से किस एक का बाकी चारों से कुछ मेल नहीं है ?

80. 4, 4, 5, 7, 10,...। इन संख्याओं के क्रम कें अनुसार आगे की एक संख्या उत्तर-पत्र पर लिखो।

81. जैसे प्राणी : पत्थर, वैसे ही जीवित : (1) चेतन (2) (अचल) (3) निर्जीव (4) कंकड़।

82. (1) ऊवधि *(2)* अब (3) परसों 4) दिन (5) सप्ताह—इन पाँचों में से किस एक का बाकी चारों से कुछ मेल नही है ?

10. Feedback is given.
11. The student is asked to list all the irrelevant attributes that he can.
12. Feedback is given.

Minor Changes

After the first step critical attributes are emphasized. Then relations of the concept with other concepts are given. Rest of the steps are the same.